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SECTION I.

MAGMATIC DIFFERENTIATION.

I. PRINZIPIELLE BEMERKUNGEN ZUM PROBLEM DER MAGMATISCHEN DIFFERENTIATION.

von

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Wie in allen Zweigen der Wissenschaft, die sich in einer erfreulich gesteigerten Phase der Entwicklung befinden, tritt auch bei dem Studium der magmatischen Differentiation die Frage nach der Wichtigkeit einzelner Faktoren, ihrem gegenseitigen Verhältnis zueinander, in letzter Zeit stark in den Vordergrund. Solche Werturteile sind jedoch für den Fortschritt oft recht gefährlich, da sie in wesentlichem Masse von der Stellung des Forschers zum Gesamtkomplexe der Fragen abhängen und Missverständnisse häufig sind. Zitate wie "I cannot endorse the statement that the volatile components have been the important factor in magmatic differentiation" können völlig irreleitend sein, solange nicht gesagt wird, was als Hauptproblem der Differentiation angesehen wird, und ob wirklich behauptet worden sei, es handle sich um *den* und nicht bloss um *einen* wichtigen Faktor. Was aber ist nun das *Hauptproblem der magmatischen Differentiation?* Der historischen Entwicklung nach ist es offenbar das folgende: Man hat erkannt, dass die magmatischen Lagerstätten eines Gebietes, sofern sie untereinander in einfacher genetischer Beziehung stehen, der gleichen räumlichen und zeitlichen geologischen Einheit angehören, verwandschaftliche Züge aufweisen und sich von andern durch charakteristische Merkmale unterscheiden. Zuerst wurde dies beim Studium der Eruptivgesteine deutlich; später jedoch konnten die Gesetzmässigkeiten mühelos auf die begleitenden Erzlagerstätten magmatischen Ursprungs übertragen werden. Die primäre Frage ist somit die: Warum sind in einer geologischen Einheit gewisse *verbindende Merkmale*, die allen zusammengehörigen magmatischen Bildungen zukommen, vorhanden und *andere* als in einer zweiten geologischen Einheit? Das Lokalkolorit und die Verscheidenheit der Lokalkolorite wil man erklären. Notwendigenweise folgt als Erstes, dass jeder ernsthafte Versuch, das Problem der Differenzierung magmatischer Bildungen in Angriff zu nehmen von *einem möglichst gründlichen, objektiven Studium der*

tatsächlich vorhandenen Assoziationsverhältnisse auszugehen hat. Die einzelnen. räumlich und zeitlich voneinander abgegrenzten Provinzen müssen mit allen modernen Hilfsmitteln statistischer Untersuchungsmetoden miteinander verglichen werden in geologisch-tektonischer, struktureller, mineralogischer und chemischer Beziehung. Jeder Versuch, nur in allgemeinen Wendungen von Assoziationsunterschieden sprechen zu wollen und daraufhin diese Unterschiede zu erklären, ist im heutigen Stadium der Forschung als unzureichend abzulehnen. Das der Fragestellung zu Grunde liegende Tatsachenmaterial bedarf einer gründlichen Verarbeitung nach einheitlichen Methoden, so dass Vergleiche möglich sind. Auf die Ergebnisse dieser Untersuchungen muss sich die Diskussion stützen; sie müssen somit *Ausgangspunkt* jeder Betrachtung sein.

Sehr wohl kann daneben eine Ausarbeitung der *Prinzipien* erfolgen, die nach *physikalisch-chemischen* Befunden als Ganzes für den Fragenkomplex in Betracht fallen; aber im Einzelnen wird es kaum möglich sein, die Bedeutung der Faktoren gegeneinader richtig abzuwägen, bevor die Unterschiede genau formuliert sind.

Bei diesen, vom Standpunkte des Physikochemikers unternommenen Untersuchungen haben nun erste Ergebnisse die Fragestellung oft sichtlich beeinflusst, so dass zwischen Ursachen und Folgeerscheinungen, Haupt-und Nebenproblemen Meinungsverschiedenheiten sich ausgebildet haben.

Die Tatsache, dass in einer geologischen Einheit chemisch und mineralogisch differente, magmatische Lagerstätten auftreten, lässt sich ja prinzipiell in ganz verschiedener Weise erklären.

1. Die Mannigfaltigkeit hat mit der Periode des Empordringens des Magmas, der Zeit gesteigerter magmatischer Tätigkeit, nichts zu tun; sie war in ganzem Umfange schon vorher vorhanden.

2. Die Ausbildung der Unterschiede fällt in die Zeit der magmatischen Intrusion und Lagerstättenbildung.

Im letzteren, nun allgemein angenommenen Falle sind bekanntlich zwei Hauptmöglichkeiten zu unterscheiden:

A. Die Mannigfaltigkeit ist eine Folge von Vermischungen weniger, bereits ursprünglich verschiedener Komplexe.' Dies können Magmen sein (z.B. wie früher angenommen, zwei herrschende Magmen), oder es kann das Magma durch Assimilation von Gesteinen seine Zuzammensetzung ändern.

B. *Ein* ursprünglich mehr oder weniger homogenes Magma hat sich im Verlaufe der gesteigerten eignen Aktivität im eigentlichen Sinne des Wortes differenziiert. Dabei ist wieder zu unterscheiden, ob angenommen wird, die Verschiedenheit der magmatischen Provinzen sei eine Folge verschiedener Differentiationsverläufe eines gleichen Magmas, oder sie sei bedingt durch ursprüngliche Unterschiede in der Zusammensetzung der sogenannten Stamm-Magmen.

Man betrachtet heute, und dies wohl mit einem gewissen Recht, vorzugsweise den Fall B, obschon jeder Petrograph weiss, dass auch Assimilationen die Zusammensetzung des Magmas verändern können, und man nimmt als teilweise wohl fundierte Arbeitshypothese an, dass nicht ursprüngliche Differenzen in der Zusammensetzung der Ausgangsmagmen absolut notwendig seien, sondern dass verschiedene Differentiationsverläufe bei *gleichem* Primärmagma sich einstellen können.

Dadurch aber hat das Problem der Magmatischen Differentiation eine *genetische* Bedeutung erlangt und des werden nun zwei Fragestellungen miteinander in Konkurrenz treten, nämlich:

(a) Warum differenziiert sich ein Magma überhaupt?

(b) Warum ist der Differentiationsverlauf zu verschiedenen Zeiten und an verschiedenen Orten ein anderer?

Est ist nun ganz selbstverständlich, dass je nachdem ob das Hauptgewicht der Erklärung auf (a) oder (b) gelegt wird, die Antworten in Bezug auf die Bedeutung einzelner Faktoren anders ausfallen werden. Bemerken wir noch, ohne die Wichtigkeit der Fragestellung (a) irgendwie zu unterschätzen, dass die ursprüngliche Problemstellung eher die von (b) war.

Zur Frage: "Warum differenziiert sich ein Magma während der Periode des Empordringens überhaupt?" ist prinzipiell Folgendes zu bemerken: Es kann sein

α) Die Differentiation ist eine einfache Folge allgemeiner Bedingungsänderungen die schon im homogenen, isotropen Feld bemerkbar sind. Sie lässt sich bei jeweilen im *ganzen System* herrschenden, *gleichen* Bedingungen experimentell untersuchen. Dazu gehören Erscheinungen wie Entmischungen in zwei Flüssigkeiten, Abspaltung einer Kristallphase ohne Saigerung und Abquetschung, Abspaltung einer Gas—oder Dampfphase, u.s.w. oder

ß) Die Differentiation im beobachteten Ausmasse kommt nur zustande, weil in Wirklichkeit das *Feld inhomogen* ist, die Intensität gewisser Faktoren in den verschiedenen Punkten des Magmaherdes eine verschiedene ist, *gerichtete Grössen* auftreten. Solche Inhomogenitäten sind zum Beispiel gegeben durch Temperaturgefälle, Druckgefälle, Gravitationsgefälle, elektrische Ströme, Unterschiede in der Beweglichkeit bei Dislokationsvorgängen, u.s.w.

Zur Zeit nimmt man wohl allgemein an, dass bereits unter α) erwähnte Erscheinungen nur wegen Existenz der unter ß) genannten Faktoren zur wirklichen Differentiation führen. Sicherlich ändert zum Beispiel die Abspaltung einer Gas-oder-Dampfphase die Zusammensetzung der Restschmelze: aber nur dadurch, dass die gasförmingen Lösungen abwandern und nicht in Form von Bläschen in der Schmelze, zurückbleiben, wird in Totalität die Zusammensetzung der Schmelze, die nun für sich erstarren kann, eine andere. Es hängt daher ganz vom Standpunkte des einzelnen Forschers ab, ob er

(bereits für diese Fragestellungen allein) das eine, das die Grundbedingung für das andere ist, als wichtiger ansieht, oder das andere, ohne das die Differentiation nicht merkbar würde.

Zu untersuchen ist in erster Linie der Einfluss, den die gerichteten Grössen auf einen irgend Zustand des Systems auszuüben vermögen. Dazu gehören zum Beispiel die Wirkungen der Gravitation und des Temperaturgefälles, die voneinander in der Natur nicht zu trennen sind. Derartige Untersuchungen zeigen die überwiegende Bedeutung, die der Zeitdauer der Einwirkung und dem speziellen Zustand des Systems (z.B. Viskosität) zukommt. Wiederum entstehen sehr verschiedene Werturteile, je nach dem ob man den eine Differentiation *begünstigenden Faktoren* nur nebensächliche Bedeutung beimisst, oder aber gerade sie, weil ihre Anwesenheit für den Ablauf einer Differentiation notwendig ist, zu Hauptfaktoren stempelt. Dadurch werden Anschauungen verschiedener Forscher, die im Grunde genommen gleichartig sind, durch falsch angebrachte Zitate oft zueinander in Gegensatz gebracht, was der Entwicklung der Lehre von der magmatischen Differentiation nur zum Nachteil gereicht. Schon die Bedeutung, die man in eine Bezeichnungsweise, wie zum Beispiel "*Kristallisationsdifferentiation*" hereinlegt, kann eine ganz verschiedene sein. Die Kristallisation allein, ohne dass äussere Umstände die Kristalle von der flüssigen Phase trennen, führt nicht zu den beobachteten Erscheinungen der Gesteinsdifferentiation. Die Faktoren aber, die eine Trennung verursachen, wirken auch sonst allgemein, so dass die Kristalle nur als Vehikel betrachtet werden können, die den Trennungsprozess ermöglichen, sofern die günstigen Faktoren vorhanden sind. Die Art der Kristallbildung ist zudem eine Folge der innern Gleichgewichtsverhältnisse der Schmelzlösungen und deren Veränderung durch die äussern Bedingungen. Es ist insbesondere *ein* Umstand, der dem Begriff der fraktionierten Kristallisation zu Gute kam. BOWEN, HOMMEL, GOLDSCHMIDT und viele andere konnten zeigen, dass für die Bildung der magmatischen Gesteine ein gewisse Richtung gegeben ist, sofern die Verknüpfüng der Differentiation mit der Kristallisation besteht: der Verfasser konnte diese Betrachtungen auf die Bildung der magmatischen Erzlagerstätten ausdehnen und hinsichtlich der Gesteinsdifferentiation auf die Möglichkeit der Umkehr (zum Beispiel lamprophyrische Magmen) hinweissen. So erwünscht es ist, eine derart einheitliche Betrachtungsweise gefunden zu haben, so sehr müssen wir uns umgekehrt darüber klar sein, dass damit gerade ein wesentliches Problem der magmatischen Differentiation noch nicht erklärt ist.

Denn wir wollen ja verstehen, warum die Differentiationsverläufe verschieden sind. Wir wollen die Frage (b) zu beantworten versuchen, nachdem einmal konstatiert worden ist, dass bei aller Variabilität manches Gemeinsame vorhanden ist. Legt man nun wiederum das Hauptgewicht auf die Erklärung der Verschiedenheit, so wird man Faktoren in den Vordergrund stellen müssen, die derjenige, welcher den gemeinsamen Gesamtverlauf als

das Wichtige ansieht, nur nebensächliche nennt. HOMMEL war neben DALY wohl der erste, der einen umfassenden Versuch auf Grund der neuern Anschauungen unternommen hat, die Manningfaltigkeit der verschiedenen Differentiation zu verstehen; manche andere, wie GOLDSCHMIDT und BOWEN sind ihm gefolgt.

Wer, was nur in beschränktem, immerhin bedeutendem, Masse zutreffen kann, von der Voraussetzung ausgeht, dass lediglich durch innere Differentiation ein und dasselbe Magma zu verschiedenen Differentiationsprodukten führen könne, wird auf dem Standpunkte stehen müssen, *dass die naturgegebene Variation der äussern, die Differentiation auslösenden oder begünstigenden Faktoren* die beobachtete Manningfaltigkeit ergibt. Verschiedene allgemeine geologisch-tektonische Bedingungen, verschiedene Intensität der Feldinhomogenität, verschiedene Zeitdauer eines für die Trennung günstigen Faktors u.s.w. sind einzeln zu berücksichtigen.

Hier wird nach der Meinung des Verfassers besonders deutlich, dass man nicht dabei stehen bleiben darf, Unterschiede auf Differenzen in der Art der Kristallisationsprodukte zurückzuführen. Denn diese selbst sind durch die innern Gleichgewichte bedingt, und da wir gerade die Möglichkeiten verschiedener Kristallisationsprodukte überblicken wollen, müssen wir die Ursachen dafür in der Verschiebung der inneren homogenen Gleichgewichte suchen. Wie sollten wie aber diese, experimentell recht schwierige Aufgabe durchführen können, ohne dass wir unsere Beobachtungen in der Natur möglichst exakt gestalten, die Variation der Differentiationsverläufe in Abhängigkeit von den geologisch-tektonischen Bedingungen wirklich genau studieren und darstellen? Wenn uns bis jetzt die Experimente an, auch so naturunwirklichen, trockenen Schmelzflüssen nur über die Kristallisationsverhältnisse unter einerlei Bedingungen Auskunft zu geben vermochten, ist dies kein Grund, über diese ersten unzulänglichen Versuche, die uns trotzdem grosse Erkenntnisse gebracht haben, nicht hinauszugehen und alle andern Betrachtungen als hypothetisch zu bezeichnen. Bei der Erklärung von Naturvorgängen, die vor langer Zeit erfolgt sind, ist nur eines zu verwerfen: Erklärungen zu versuchen ohne genaue Darstellung des Beobachtbaren und ohne genaueste Berücksichtingung aller zur Verfügung stehenden, physikalisch-chemischen, theoretischen und experimentellen Resultate.

Auf Grund dieser Erwägungen möchte der Verfasser vorschlagen:

1) Der Methode der *Beschreibung magmatischer Provinzen* (in räumlichem und zeitlichen Sinn) besondere Sorgfalt angedeihen zu lassen. Am zweckmässigsten wäre es, wenn man sich bei der Darstellung gewisser grundlegender Erscheinungen auf eine *Norm* einigen könnte, die den Vergleich ermöglichen würde. Vorschläge, zum Beispiel hinsichtlich der chemischen Berechnung und der Konstruktion von Differentiationsdiagrammen, sind mehrfach gemacht worden; der Verfasser selbst hat einen derartigen Versuch unternommen.

2) Dem theoretischen und experimentellen Studium der *Faktoren,* die zu *Gleichgewichtsverschiebungen* in Schmelzen führen, sowie der in einem Magmaherd von Ort zu Ort *variablen Faktoren* besondere Aufmerksamkeit zu schenken, ohne von vornherein nach scheinbarer Wichtigkeit oder Unwichtigkeit gliedern zu wollen.

Die erste Phase der wissenschaftlich begründeten Lehre von der magmatischen Differentiation, die im Wesentlichen von den experimentellen Befunden der Kristallisation in trockenen Schmelzflüssen ausging, ist bis zu einem gewissen Grade als abgeschlossen zu betrachten; es gilt in klarer Weise die nächste, weit schwierigere Phase der Forschung zu organisieren.

2. THE LAST STAGE OF MAGMATIC DIFFERENTIATION, AS REPRESENTED BY TERTIARY GOLD-SILVER VEINS.

BY

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I. *Introduction.*

Gold-silver quartz veins genetically connected with the Late Tertiary volcanic activity abound in Japan. They are found in volcanic rocks such as rhyolites and andesites, and their tuffs, or in Tertiary sedimentary rocks underlying the flows of those igneous rocks or cut by the dykes of them.

I have elsewhere (1) stated that the effusion of these volcanic rocks, the propylitization silicification and other alterations of these rocks as the country rocks, and the formation of hydrothermal gold-silver quartz veins belong to one and the same magmatic cycle, related to the solidifying magma at a relatively shallow depth under cryptobatholitic conditions.

In this paper I intend to give some suggestions as to the chemical composition of the mineralizing solutions with special reference to the modern theory of magmatic differentiation.

II. *The Alteration of the Wall Rocks.*

As is well known, the walls of Tertiary gold-silver veins, especially where they are represented by volcanic rocks, are more or less hydrothermally altered-Alunitization, kaolinization and pyropylitization are sometimes recognized in the rhyolite forming the wall of those veins formed at very shallow depths by hydrothermal solutions containing free sulphuric acid. But they are rather rare. Propylitization and silicification are the prevailing hydrothermal alterations of the wall rocks of Tertiary gold-silver veins. Andesitic rocks are often propylitized, whereas rhyolitic rocks are usually silicified. These two kinds of alterations are characterized by quite different characteristics so that they should be considered separately.

(1) T. KATO: Some Characteristic Features of the Ore Deposits of Japan, related genetically to the Late Tertiary Volcanic Activity. Jap. Journ. Geol. Geogr., Vol. VI, Nos. 1-2 (1928) pp. 31-48.

(A.) *Propylitization*:—

By propylitization is meant an alteration of volcanic rocks, chiefly of intermediate or basic composition, into a dull green rock, called propylite, with impregnated minute crystals of pyrite. In it, mafic minerals are all changed to chlorite. Plagioclase phenocrysts are exceedingly altered, and the ground-mass has become holocrystalline, being composed of grains and crystals of newly developed felspar, scales and flakes of chlorite and sericite grains of leucoxene and partially decomposed titano-magnetite, and others. Pyrite is usually finely crystallized in cubic crystals.

As can be revealed under the microscope, the essential change involved in the so-called propylitization consists in the alteration of the original limesoda felspars into albite or potash-albite and the introduction of the same alkali-felspar in the groundmass. I have examined the propylites from the Sade mine in the province of Sade, the Tohi mine in the province of Idzu, and many other gold-silver mines in Japan and found that they show every stage of albitization or potash-albitization of the plagioclase phenocrysts. The change has commenced along the cleavage cracks and margins of the plagioclase, forming nets of alkali-felspar, and finally resulted in the entire replacement by albite or potash-albite. The alteration-products preserve the original outlines of the plagioclase, but usually show no twinning lamellae. As the albitization of the phenocrystic plagioclase has advanced the groundmass begins to be changed. The felspar laths suffer the same change as the phenocrysts, the glass base becomes devitrified and finally the groundmass has become granular, consisting of newly formed crystals and grains of albite or potash-albite intimately commingled with chlorite flakes, sericite scales and grains of partially decomposed iron ore.

The propylitization generally represents the first stage of mineralization in the formation of gold-silver veins, the veins themselves being the products of repeated mineralizations of subsequent stages along reopened fissures. It is beyond all doubt that the propylitization has been effected by a hydrothermal metasomatism.

(B.) *Silicification*:—

Silicification of the wall rock of gold-silver veins is most characteristically demonstrated where the rock is rhyolite, as in the Takatama mine in the province of Iwashiro, and others. In this case the altered rock is composed, under the microscope, of very fine interlocking grains of quartz commingled with abundant fine scales of sericite, more or less flakes and grains of red iron oxide, etc., the original texture of the rock being entirely obliterated in highly altered specimens.

When a propylitized andesite forms the country rock as in the veins of the Tohi mine and the Rendaiji mine in the province of Idzu, propyliti-

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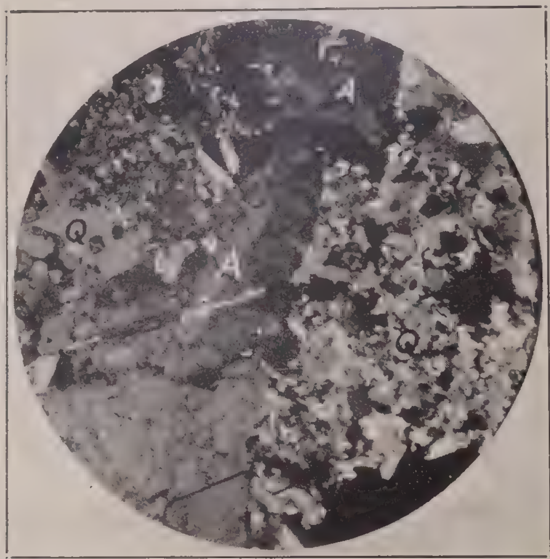

Fig. 1. Communication No. 2.

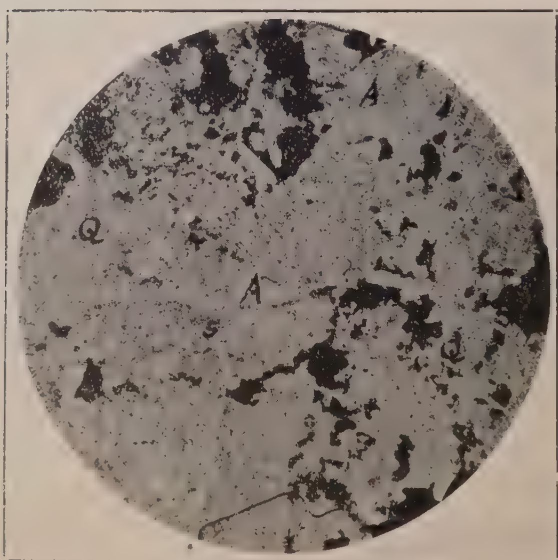

Fig. 2. Communication No. 2

Fig. 1. Photomicrograph of wedge-shaped orthoclase (adularia) from the Sade mine (A), surrounded by fine-grained quartz (Q), admixed with xenomorphic sulphides (black). Note the sulphides cementing the grains and crystals of quartz, and cutting the adularia. Magnified 20 diameters. Ordinary light.

Fig. 2. Ditto between crossed Nicols.

zation is overlapped by silicification, especially on both sides of the veins. The propylitization had always preceded the silicification. The propylitized and silicified andesite is, as observed under the microscope, usually intricately traversed by netted veinlets and stringers of quartz. At earlier stages of silicification, the ground-mass of the propylite is commingled with fine grains of quartz sometimes with abundant scales of sericite; in more advanced stages the groundmass has become almost entirely replaced by fine grains of quartz and the albitized phenocrystic felspar is replaced by larger grains of quartz, with the chlorite after mafic minerals untouched; at last the rock is altered to a fine-granular quartz aggregate commingled with fine flakes of chlorite scales of sericite and residual iron ores — hematite and magnetite.

Rhyolitic rocks when attacked by hydrothermal solutions are first albitized, that is to say, the plagioclase and sanidine as phenocrysts and in the groundmass are albitized, but later on they are silicified when the porphyritic texture is entirely destroyed and the rocks become composed of fine grains of quartz.

III. *Vein Filling.*

Most of the Tertiary gold-silver veins formed by repeated opening of the fissures and repeated mineralizations. A general rule seems to exist in the succession of mineralizations in the formation of them, but I would not go further in this problem in the present paper. One of the most characteristic features of the veins in question is the occurrence of orthoclase as an important gangue mineral. The occurrence of orthoclase is not rare, as was formerly thought. I found it in almost all gold-silver quartz viens of the Tertiary age, either as a macroscopbic or microscopic gangue mineral. I cite here two conspicuous examples.

In the Sado mine, already cited, there are many parallel gold-silver veins running E-W and some diagonal veins cutting through the Tertiary formation, consisting of shales, sandstones, tuffs and tuff-breccias with intrusive and extrusive propylitized andesites and silicified liparites. The veins are composite in nature, having been formed by repeated opening of the fissures and repeated depositions of quartzose material. It is very conspicuous that in almost all the veins orthoclase (Ref. Indices: $\alpha = 1.514$, $\beta = 1.522$) showing a typical wedge-shaped section makes its appearance as a gangue mineral towards deeper parts. (Figs. 1, 2). Usually quartz predominates over felspar, but at many places the two minerals occur in almost equal proportions or even with prevailing felspar.

In the Tohi mine, also already cited, numerous parallel gold-silver veins running N. 20 deg. W. are found in the complex of tuffs, agglomerates and flows of pyroxene andesites of the Neogene age. All the country rocks

are extensively and intensely propylitized. On close observation and examination of the veins, the following succession of mineralizations has been established:—

(1) Extensive propylitization of the andesites and agglomerates;

(2) Deposition of the quartz vein of the first stage containing abundant microscopic adularia;

(3) Deposition of colloidal quartz, now transformed into chalcedony, with abundant sulphides and sulphosalts. The quartzose ore of this stage is very rich in gold and silver, but contains no adularia, but abundant sericite scales;

(4) Repeated depositions of barren quartz veins;

(5) Deposition of calcite in veins representing the last mineralization.

IV. *Conclusion.*

As proved by microscopic examination of numerous examples from Japan, the propylitization of the country rock of the Tertiary gold-silver veins comprises essentially the formation of albite and potash-albite at the expense of the original lime-soda felspars, whereas the silicification of the wall rock is always characterized by the mixing of abundant sericite. These facts, together with that that quartz veins themselves contain very commonly more or less adularia or sericite, indicate that the hydrothermal solutions representing the residual liquid of the last stage of magmatic solidification are very rich in alkali metals. In other words, the hydrothermal solutions causing the formation of the Tertiary gold-silver quartz veins and representing the last stage of magmatic solidification at a relatively shallow depth are characterized by the concentration of alkali metals in them. This fact agrees well with the principle of magmatic differentiation [1] due to fractional crystallization of the component minerals and reaction between the earlier minerals and the residual liquid.

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[1] Refer to C. S. Ross: Physico-Chemical Factors Controlling Magmatic Differentiation and Vein Formation. Econ. Geol. Vol. XXIII., No. 8. pp. 864-886 (1928.)

3. THE SUDBURY NICKEL INTRUSIVE.

BY

A. P. COLEMAN, E. S. MORE and T. L. WALKER.

ABSTRACT.

The authors were among those who were active in field work in this region in the early history of Sudbury geology. In 1928 they spent some weeks going over the field with a view to finding what modifications were really necessitated in their earlier conclusions as a result of later studies. Analyses were made of series of rocks collected in four traverses across the eruptive while a large number of thin sections were examined. As a result of chemical, microscopic, and field studies they are still of opinion that:—

1. The norite-micropegmatite represents a single intrusion which has by magmatic differentiation separated into a heavier rock, norite, at the bottom, passing upward without a sharp break into micropegmatite.

2. The great deposits of nickel-copper ores are to be regarded as the extreme heavy differentiate from the intrusive; very little hydrothermal action is to be seen in the ores of the marginal deposits although in some of the offset deposits the rearrangement is more marked.

3. Studies based on examination of thin sections of the rocks of the intrusive with a view to determine the relative proportion of the constituent minerals when applied to the micropegmatite phase, have in the past given misleading results as the rocks are too fine grained for such study.

4. The dark phase of the intrusive may appropriately be called norite since the rhombic pyroxene is always more abundant than the monoclinic, and when as often happens, the pyroxene is replaced by secondary hornblende, the nature of the original pyroxene is not open to doubt.

4. SUR LES TRANSFORMATIONS HERCYNIENNES D'ORIGINE DYNAMIQUE ET MAGMATIQUE DANS LES CEVENNES ET DANS LE MASSIF DES MAURES.

PAR

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Dans les Cévennes et peut-être aussi dans le massif des Maures, le métamorphisme régional qui a donné naissance à la série cristallophyllienne primitive et au granite de base est probablement d'âge hercynien. En effet non loin du domaine cévenol, dans le Lyonnais, il résulte des observations de M. Alb. MICHEL-LEVY que des sédiments à facies dévonien passent à des schistes métamorphiques. Ceux-ci passent eux-mêmes à des gneiss feuilletés et è des gneiss oeillés analogues à ceux des Cévennes. Un peu plus au nord le tournaisien et exceptionellement le viséen ont été métamorphosés par le granite intrusif. Les produits cristallophylliens ou cristallins de ce métamorphisme régional ont été ensuite déformés ou écrasés par les mouvements de la phase hercynienne principale qui est antéstéphanienne aussi bien dans les Maures que dans les Cévennes. Enfin un métamorphisme ultérieur lié à des venues éruptives posttectoniques et beaucoup moins étendu que le métamorphisme initial a donné naissance en particulier aux gneiss granulitiques cévenols. Nous examinerons d'abord les transformations d'origine magmatique, c'est-à-dire dans les Cévennes le métamorphisme initial et le metamorphisme granulitique, puis les transformations d'origine dynamique.

I *Origine et degré métamorphique du cristallophyllien des Cévennes et des Maures.*

La séparation des orthogneiss et des paragneiss, qui fut introduite par ROSENBUSCH, n'intervient pas dans la théorie de M. P. TERMIER sur la genèse simultanée des terrains cristallophylliens et cristallins à partir des terrains sédimentaires.[1] Pourtant qu'elle que soit la théorie admise, il y

[1] P. TERMIER — Sur la genèse de terrains cristallophylliens C.R. XI. Congrès Géol. Inter. Stockholm 1910, T. 2 page 587.

a intérêt pour faciliter la comparaison d'un domaine à l'autre, à utiliser des termes communément employés, à condition toutefois de préciser le sens qu'on leur attribue. Primitivement les orthogneiss étaient considérés comme des roches éruptives transformées en roches cristallophylliennes par les actions dynamiques, mais aujourd'hui la plupart des pétrographes admettent en outre qu'une roche peut cristalliser initialement avec une structure schisteuse (Primäre Druckschieferung de Grubenmann et Niggli) et ils donnent à une telle roche le nom d'orthogneiss en raison de son origine probable et de sa parenté avec une roche éruptive massive. C'est ce qu'on pourrait appeler des orthogneiss magmatiques. Leur formation s'accorde parfaitement avec la théorie de M. Pierre Termier. Quant aux phénomènes dynamiques, ils développent parfois une schistosité de laminage accusée par le cristallisation d'éléments secondaires, Mais il est beaucoup moins évident qu'ils aient jamais donné naissance à de véritables gneiss au "orthogneiss dynamiques" sans qu' il y ait eu une nouvelle phase de métamorphisme régional (au sens français par élévation de température et apport chimique). La séparation des orthogneiss magmatiques et des paragneiss qui pourrait théoriquement être basée sur la nature du milieu de cristallisation, liquide ou solide, reste elle aussi assez artificielle en raison de l'absence d'un point de fusion déterminé pour les mélanges de silicates. Quoiqu'il en soit, on peut définir les orthogneiss et les paragneiss d'une manière concrète par les caractères suivants, pour les premiers une composition chimique voisine de celle d'une roche éruptive, le développement et l'idiomorphisme des cristaux feldspathiques, l'existence d'un ordre de cristallisation, pour les seconds une composition chimique differente, une structure grenue sans ordre de cristallisation et souvent sans forme cristalline, une disposition plus nettement schisteuse et une plus grande hétérogénéité.

Si l'on tient compte de ces remarques et si l'on adopte la classification des roches métamorphiques de Grubenmann et Niggli, on doit dire que dans l'ensemble le cristallophyllien des Cévennes et des Maures est paragneissique. Les gneiss oeillés ne proviennent certainement pas du laminage d'une roche éruptive et sont aussi des paragneiss. Seuls les gneiss granitoïdes du substratum autochtone et de la nappe de Pouyardière dans les Cévennes doivent être considérés comme des orthogneiss magmatiques. D'autre part le cristallophyllien cévenol appartient aux zones méso et catamétamorphiques. Dans les Maures la zone épimétamorphique est représentée en outre par des phyllades. L'ordre normal de superposition des facies orthogneissique, catamétamorphique et mésométamorphique a été souvent inversé par les phénomènes tectoniques (nappes cévenoles et plis déversés du massif des Maures.)

M. Pierre Termier a signalé depuis longtemps le passage continue de la roche éruptive à la roche cristallophyllienne. On peut ajouter que sur le terrain et au microscope, le cristallophyllien à facies voisin du facies

massif (orthogneiss magmatique) passe du cristallophyllien rubanné normal (paragneiss), ce qui confirme la théorie et montre la difficulté de séparer orthogneiss et paragneiss parfois étroitement associés.

II. *Le métamorphisme et les venues éruptives posttectoniques.*

Les granulites massives (granites à deux micas) des Cèvennes apparaissent dans le granite, dans les gneiss et même dans les micaschistes sous forme de grands filons, d'amas irréguliers ou de lentilles interstratifiées. Leur répartition est indépendante, de toute limite tectonique. La granulite intacte traverse parfois et absorbe des amas mylonitiques. Au microscope, on observe les éléments anciens (quartz, feldspath, biotite) déformés ou broyés, et transformés par une métasomatose liée au broyage en chlorite, limonite ou en une pâte amorphe, et les éléments intacts d'une seconde cristallisation (quartz granulitique ou en plage, oligoclase, moscovite.) Entre La Valla et Condrieu-sur-le Rhône des solutions hydrothermales siliceuses qui sont en relations avec les vennes granulitiques ont imprégné les roches broyés à la base d'une nappe et donné naissance à des brèches de nappe filoniennes. Les granulites cévenoles sont donc postérieures aux écrasements et par suite au charriage du cristallophyllien. Les gneiss granulitiques aux-mêmes résultent de la granulitisation de la série cristallophyllienne primitive. Les produits de ce métamorphisme granulitique sont pour une part (granulites gneissiques) des orthogneiss magmatiques liés aux granulites massives, pour unie autre part des gneiss d'injection qui se sont développés au detriment de paragneiss antérieurs.

Dans le massif des Maures, le granite porphyroïde du Plan de la Tour a une allure intrusive très différente de celle d'un granite de base lié au cristallophyllien. Le granite et des pegmatites qui s'y attachent directement et sont comme lui tout à fait intactes traversent avec un dessin capricieux les gneiss de St. Tropez laminés. Le granite du Plan-de-la-Tour est donc, comme les granulites Cévenoles, une venue éruptive posttectonique qui a injecté le crystallophyllien après les mouvements principaux.

III. *Transformations dynamiques.*

La poussée et le charriage du cristallophyllien et du cristallin ont donné naissance dans les Cévennes et dans les Maures à des roches laminées et à des mylonites de divers types, roche aphanitique sans structure de couleur brune ou verdâtre, gneiss oeillé à felspath disloqués, fausse brèche et fausse arkose à grands éléments des Cévennes, fausse arkose à petits grains qui provient du laminage du gneiss de St. Tropez dans les Maures et que l'on peut confondre à première vue avec un grès houiller, etc. . .

Ces phénomènes dynamiques n'ont transformé en aucun point les roches éruptives en roches cristallophylliennes. Les mylonites granitiques n'ont pas

une structure schisteuse. Au contraire l'étude micrographique démontre par l'observation de nombreux types de transition que dans les roches initialement gneissiques, l'orientation des éléments et la disposition en bandes parallèles ont été progressivement effacées par le laminage et parfois complétement détruites. A un degré d'écrasement suffisant une mylonite de gneiss prend ainsi l'aspect d'une mylonite granitique. L'observation de traces de l'organisation gneissique dans les *parties les moins écrasées,* permet pourtant de déceler la roche originelle. Ce processus dynamique, inverse de celui qui est souvent invoqué pour justifier la formation de gneiss à partir du granite, apparaît clairement dans les gneiss mylonitiques des Cévennes et dans ceux du massif des Maures.

5. GENESIS DER EISENERZE DER ABAKAN'SCHEN EISENHÜTTE.

(Der Fall einer weitgehenden Differenziation des Magmas nach dem Gravitätsgesetz.)

VON

A. VLASSENKO,
Stalin (Donbass). Ukraina.

Die Abakan'sche Eisenhütte befindet sich im Bezirk Minussinsk, Gouv. Jenissei, am Ufer des Flusses Abakan, einem Nebenflusse des Jenissei. — Die Coordinaten der Abakanlagerstätte sind: 50° 41' 55, "8 N.B. und 90° 16' 47, "55 WL. von Greenwich. —

Die geologische Beschaffenheit laut letzteren Erforschungen von PROF. USSOW (12) weicht von den Beschreibungen des PROF. BOGDANOWITSCH (die Eisenerze Russlands aus "The Iron Ore Resources of the World" — Stockholm, 1910) ab und ist auf beifolgendem, VON USSOW zusammengesetztem geologischen Kärtchen, dargestellt (s. Fig. 1). —

Das Kusnetski-Alatau Gebiet wird gegenwärtig auf Grund der Forschungen, hauptsächlich derjenigen VON TOLMATSCHEW (11 s. 109, 679, 695, 715) und W. OBRUTSCHEW (8 s. 299, 300) als ein Teil des SUESS-schen "Alten Scheitels" von Asien betrachtet (s. Fig. 2).—SUESS selbst, wie bekannt, hat dem Kusnetzki-Alatau mehr jüngeres hercynisches Alter zugesprochen (10-S.197, 199-202, 249-50).—

Der Kusnetzki-Alatau besteht aus stark erodierten Falten von Gestein eosoischen Alters (Kristalline Kalksteine, Quarzit-Tonschiefer, vulkanische Tuffe) und war Anfang Kambrium vom östlichen Teile des "alten Scheitels" durch eine Einsenkung in der Gegend von Minussinsk abgetrennt. — Der gesunkene Teil war vom kambrischen Meer, aus dessen Wässern sich Konglomerate, Tonschiefer, Kalksteine mit *Archeacyatus* niederschlugen, eingenommen. — Das verseichte Meer verliess das Minussinskbecken wahrscheinlich Ende Kambrium. —

Auf Ende Silur — Anfang Devon wird die Dislokationserneuerung in diesem Gebiet, die von einem neuen Erscheinen des Meeres in diesem Becken begleitet wurde, bezogen. — Was Meer verblieb in den Grenzen des Minussinskgebietes während des Devon und teils des Karbon. —

Die devonischen Niederschläge bestehen hauptsächlich aus Sandsteinen und Kalksteinen, die karbonischen — aus Sandsteinen, Kalksteinen, Tonschiefer mit Pflanzenresten und Schichten von Steinkohle. —

Zwischen den jüngeren, den Minussinskbecken ausfüllenden Niederschlägen, und den älteren, dieses Becken umgebenden Horsten — dem Kusnetski-Alatau nach W und seiner Fortsetzung, — dem Sajan, nach O — tritt eine Zone effusiver Gesteine (Porphyrite, Melaphyre, Diabase) devonischer Herkunft hervor. —

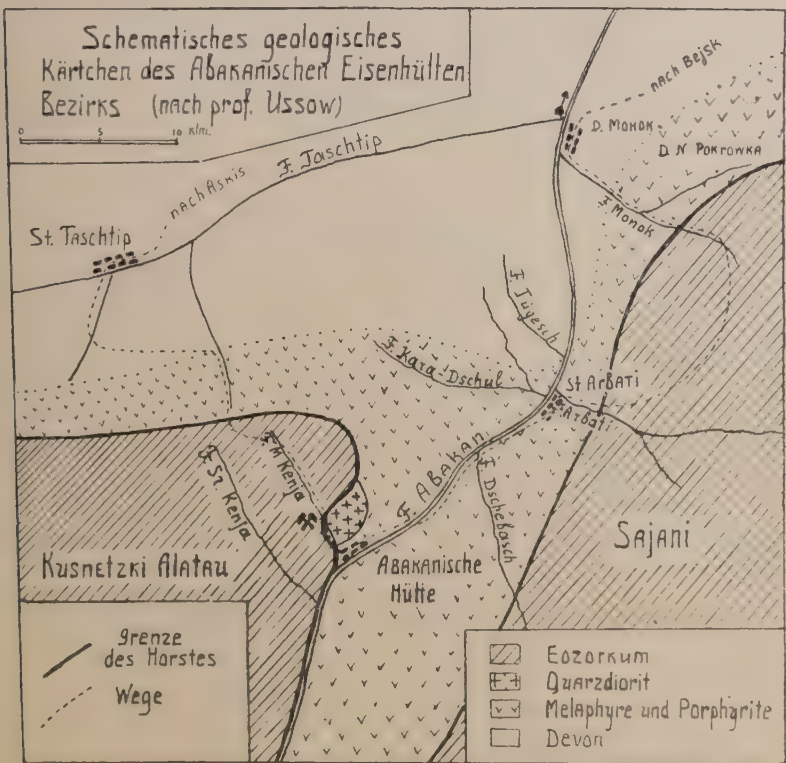

Fig. 1

Nun wollen wir zu den Abakan-Lagerstätten zurückkehren. —

Die alleráltestem Gesteine in der Umgegend der Hütte sind — weisse, graue und schwarze marmorartige Kalksteine, eosoischer Herkunft. —

Mit diesen nicht übereinstimmend liegen in der Nähe der Hütte die stummen Schichten von Konglomeraten, Grauwacken, Kalksteinen und Schiefer, meistens von grünlichgrauer Farbe, welche als Niederschläge im seichten Wasser des kambrischen Meeres angesehen werden müssen, während Niederschläge im tiefen Wasser (Kalksteine mit Archeocyathidae) in der Nähe des Dorfes Monok gefunden worden sind. —

Diese Gesteine werden von einer Effusivdecke aus Plagioklasporphyriten bedeckt, welche nach ihrem Gebilde, denjenigen ähnlich sind, die sich an der Grenze der Ausdehnung von eosoischen und kambrischen mit devonischen Gesteinen befinden (s. Oben). —

Das unterdevonische Meer, nach seinem Verlassen des Minussinsker Grabens in der Umgegend der Hütte, hat Spuren seines Aufenthaltes hinterlassen in Form von rotfarbigen Sandsteinen und Konglomeraten, enthaltend abgebrochene Stücke aus den darunterliegenden Porphyriten. —

Auf die vulkanische Phase der obersilurisch — unterdevonischen Periode muss wahrscheinlich die sich im Gebiet der Lagerstätte an die Spalte der Dislokation anschmiegende Intrusion von Lakkolith (mit Bildung von recht zahlreichen Apophysen), Quarzdiorit, welcher die kambrischen Niederschläge und die darüberliegende Decke von Porphyriten empordrückt, bezogen werden. —

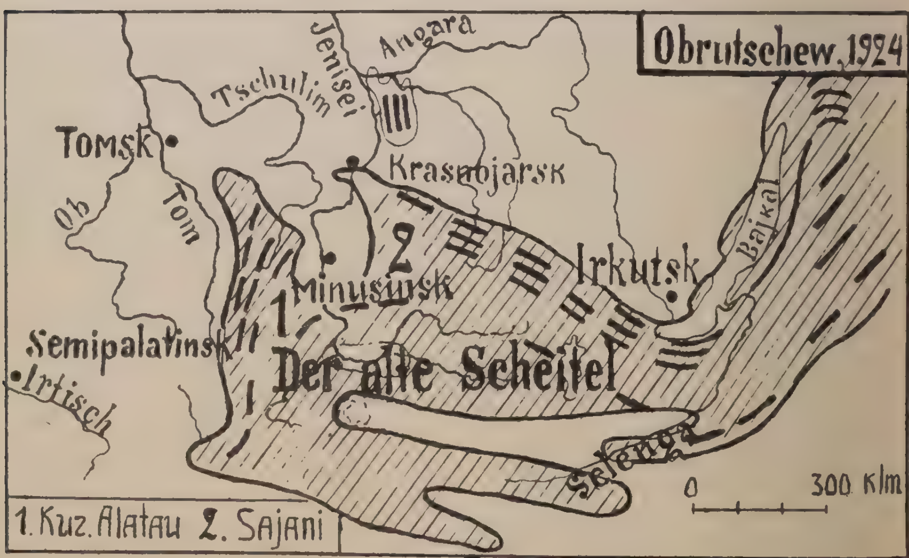

Fig 2.

Mit der Intrusion dieses Gesteins ist die Erzlagerstätte genetisch verbunden. —

Heute hat die Erosion einen Teil der Gesteine, welche den Lakkolith bedeckten, fortgetragen, hierdurch diesen teilweise entblössend, was bereits Spuren von Differenziation nach dem Gravitätsgesetz, welcher das Lakkolithmagma unterworfen war, erkennen lässt. —

Der durch Erosion freigelegte Teil des Lakkoliths stellt einen aus Quartz, alkalischem Plagioklas und sehr geringer Menge Amphibol bestehenden Alaskyt vor. —

Die Gesteine des durch den erfolgten Druck etwas zerquetschten Lakkoliths, wie auch die ihn umgebenden, sind von recht zahlreichen Spalten durchbrochen, die mit durch Tangentialkräfte herausgepressten Differenziationsprodukten des Lakkolithmagmas (Quarz-albitphyr, Alaskyt, Plagioklas-porphyrit, Augitporphyrit) ausgefüllt sind. —

Das Erz (Magnetit), welches eine Lagerstätte von ungefähr 1, 5 Kilometer vom Lakkolith einnimmt, ist gleichfalls die Folge eines der Fazien (eines allertiefsten) der Magmadifferenziation, und ist in gleicher Weise durch die in dieser Gegend sich abgespielten tektonischen Prozesse herausgepresst worden. —

Zu der Lagerstätte selbst übergehend ist zu bemerken, dass, auf Grund magnetometrischer Aufnahmen des Berging. Kell (4-S. 24-6) die Form der Ablagerung des Erzes und die Ausdehnung der Lagestätte von ihm in folgender Weise bestimmt worden ist: die Ausdehnung der Erzmasse nach dem Streichen ist etwas über ein Kilometer; die Erzmasse besteht hauptsächlich aus drei stockförmingen Lagerungen. —

Die erste ("Abakanische Blagodat"), der Form nach, ist ein Stock gleicher Dimensionen (ungefähr 80 Meter) nach verschiedenen Richtungen, der einen Einfall nach S. hat. —

Die zweite Lagerung schliesst sich an die erste an und stellt einen in meridionaler Richtung ausgedehnten Stock von 200 Meter Länge und circa 40 m. Breite dar, einfallend nach S. —

Die dritte — die grösste, Ausdehnung ungemähr 800 m. — Der Form nach — ein ausgedehnteer Stock mit steilem Einfall nach SO. —

Der effektive Vorrat an Erz in der gesammten Lagerstätte beträgt ungefähr 5.000.000 T. —

Das Erz — Magnetit — ist grösstenteils gleichartig, feinkörnig mit Ausscheidung in den recht zahlreichen in ihm befindlichen Spalten von Pyrit, Kupferkies, Calcit; andere oft angetroffene Beimischungen sind Quarz, Chlorit. —

In den oberen Zonen ist das Magnetit in Brauneisen verwandelt; Kupferkies — in oxydierte Kupferverbindungen. —

Die Erzlagerstätte liegt in geringer Tiefe untertage; viele Lagerungen gehen unmittelbar bis auf die Oberfläche und die Arbeiten werden in offenen Abbauen vorgenommen. —

Die Nebengesteine der Lagerstätte sind — Plagioklasporphyrite grünlichgrauer Farbe, stark verändert, mit reichlicher Ausscheidung im Gestein von Chlorit, Epidot, Calcit. —

Die Abscheidung des Erzes von dem Nebengestein ist ziemlich scharf; das Erz wird grösstenteils in Form von kompakten Massen angetroffen Sich vom Nebengestein abgeteilte Stücke werden in ihm selten vorgefunden. —

Genesis der Lagerstätte. — Wie schon früher erwähnt, fand Ende Silur oder Anfang Devon im Bezirk der Abakanischen Lagerstätte eine Intrusion des Quarzdioritmagmas statt, welches in Form von Lakkolith erstarrt war, hierbei die kambrischen Schichten und die Decke von Porphyriten hervorbiegend. —

Die dabei entstandenen Spalten wurden mit diesem Magma gefüllt unter Bildung von Apophysen. —

Das intrusierte Magma, infolge starker Abkühlung an der Stelle der Berührungsfläche mit den Nebengesteinen, war zu schnell ohne Differenziationserscheinungen erstarrt. —

Dieser "Panzer," der sich durch geringe Wärmeleitung auszeichnete schützte das magmatische Bassein vor schneller Abkühlung und übte eine günstige Wirkung auf die Magmadifferenziation aus. —

Die chemische Zusammensetzung dieses "Panzers" ist sehr wichtig für die Beurteilung der primären Bestandteile des Lakkolithmagmas. — In dem durch den "Panzer" geschützten Magma spielten sich Differenziationsprozesse ab, die zur Konzentration der specifisch schweren Fe-Verbindungen in den tiefsten Teilen des Lakkolith führten. —

Von Morozewicz (6-S. 232) vorgenommene laboratorische Versuche zeigten, dass sogar in einer geringen Masse (im Tiegel) geschmolzener Gesteine Differenziationserscheinungen nach dem Gravitätsgesetz in klar wahrnehmbarer Weise vor sich gehen. — Obgleich der Wert der Versuche von Morozewicz seitens Bowen (3-S. 5) angezweifelt wurde und die vom Ersteren angeführten Ziffernwerte für die Verhältnisse zwischen den Oxyden vielleicht keine *absolute* Bedeutung haben könnten, so ist doch der *relative* Wert seiner Untersuchungen — die Erscheinung der vorherrschenden Konzentration, infolge des Gravitätsgesetzes, einiger Oxyde im oberen Teile der langsam abkühlenden Masse, und der anderen im unteren Teile noch nicht bestritten worden. —

Die Erscheinung der Differenziation des Magmas nach dem Gravitätsgesetz war noch vor Morozewicz von Vogt bei der Untersuchung einer Reihe von Erzlagerstätten bemerkt und von ihm gleichfalls die Gesetzmässigkeit in dem Gehalt von Oxyden beobachtet worden, und zwar: vorherrschende Konzentration von SiO_2, K_2O, Na_2O, im obenliegenden Teil des abkühlenden Magmas und TiO_2, Fe_2O_3, FeO, MgO, und CaO im untenliegenden Teil (14). —

Diese Gesetzmässigkeiten der Oxydenverteilung sind, wie bekannt, von Vogt aus Forschungen über die Bildung von Fe-Erzlagerstätten in basischen Gesteinen gefolgert worden. —

Was die Bildung der Fe-Erzlagerstätten in sauren Gesteinen anbetrifft,

so erscheinen die Bedingungen in diesem Falle weniger günstig (geringere Prozente Fe-oxyde in Magma), obgleich dieses durchaus möglich ist, was von demselben Autor berichtet wurde. — Vogt hat gleichfalls über den Unterschied in den Bestandteilen des Fe-Erzes in Fällen seiner auf dem Wege der Differenziation nach dem Gravitätsgesetz aus sauren Gesteinen Mitteilung gemacht: erheblich geringerer Gehalt an TiO_2 infolge, wie überhaupt, seines wenigeren Gehaltes in saurem Gestein im Vergleich zum basischen, so auch infolge seines vorherrschenden Anteils im Titanit und nur in kleineren Masse in Fe-Ti-Verbindungen (Vogt Z.f. pr. Geol. 1893 S. 281 und and. — Newland 7-S. 32.)

Da in der Umgegend der Abakanischen Eisenhütte zutagetretende Gesteine, die ein Verständnis über den Character der Veränderungen der Zusammensetzung der Lakkolithgesteine, bei zunehmender Tiefe, infolge von Differenziation bieten könnten, nicht vorhanden sind, so ist es erforderlich eine indirekte Methode der Erforschungen dieser Veränderungen vorzunehmen. —

Wie schon oben erwähnt, erlitt nach der Magmaintrusion die abgekühlte Form des Lakkoliths — der Rayon der Abakanischen Lagerstätte — starke tangentiale Spannung. —

Zu den characteristischen Richtungen des Streichens der Spalten in diesem Rayon gehören folgende:

1.) Meridionale oder diesen annähernde;

2.) Breitengradige oder diesen annähernde;

3.) Streichende Spaten von 130° oder 310° mit einem entsprechendem Einfall nach S.W. der ersteren und nach NO der letzteren. — Bei allen drei Systemen der Spalten ist ein steiles Fallen vorherrschend. —

Das Bassin, in welchem die Abkühlung des Magmas vor sich ging, musste einer Zusammenpressung unter Einwirkung dieser Kräfte unterworfen werden. — Die Folge hiervon war eine Auspressung der noch nicht erstarrten Magmamasse durch die Spalten in einer ungefähr senkrechten Richtung zu derjenigen der Kraftwirkung. —

Somit entstanden Gänge, angefüllt mit Produkten der Magmadifferenziation (Quarzalbitophyr, Alaskyt, Plagioklasporphyrit, Augitporphyrit und Erz), welche, als entblösste Erosion, den oberen Teil des Lakkoliths, wie auch die das Lakkolith umgebende Gesteine, durchschneiden. —

Nach Niederschreibung einer Reihe von chemischen Analysen des Urmagmas und seiner aufgezählten Derivate erhalten wir, nach Abzug von H_2O und Uebertragung auf 100, Folgendes:

TABLE I.

TABELLE 1.

	SiO^2	TiO^2	Al^2O^3	Fe^2O^3	FeO	CaO	MgO	Na^2O	K^2O	W
Quarzdiorit	58·72	0·50	17·29	4·39	3·83	6·08	3·66	4·82	0·71	100·00
Quarzalbitophyr	75·15	0·12	14·68	0·25	0·33	1·14	0·62	6·38	1·33	100·00
Alaskyt (Lakkolith)	71·56	0·25	14·47	0·99	0·72	2·68	0·93	7·13	1·27	100·00
Alaskyt (Gang)	68·48	0·25	18·11	0·74	0·55	2·48	1·60	6·77	1·02	100·00
Plagioklasporphyrit ..	58·19	0·24	21·43	1·47	1·21	7·96	4·85	3·93	0·72	100·00
Augitporphyrit	46·97	0·87	20·13	8·68	7·20	8·02	4·86	2·84	0·43	100·00
Erz	12·37	1·02	7·20	57·83	16·54	2·14	1·96	0·85	0·09	100·00

oder nach Umrechnung auf molekuläre Prozente:

TABELLE 2.

	SiO^2	TiO^2	Al^2O^3	Fe^2O^3	FeO	CaO	MgO	Na^2O	K^2O	W
Quarzdiorit	64·0	0·4	11·4	1·9	3·5	7·1	6·0	5·2	0·5	100·00
Quarzalbitophyr	80·4	0·1	9·3	0·1	0·3	1·3	1·0	6·6	0·9	100·00
Alaskyt (Lakkolith)	76·4	0·2	9·1	0·4	0·7	3·1	1·5	7·4	0·8	100·00
Alaskyt (Gang)	74·5	0·2	11·4	0·3	0·5	2·8	2·6	7·0	0·7	100·00
Plagioklasporphyrit	62·6	0·2	13·8	0·6	1·1	9·3	7·8	4·1	0·5	100·00
Augitporphyrit	53·5	0·7	13·5	3·7	6·9	9·8	8·4	3·2	0·3	100·00
Erz	21·0	1·3	7·2	36·8	23·3	3·9	5·0	1·4	0·1	100·00

Trotz der bei mikroskopischen Untersuchungen beobachteten Verwitterung der Gesteine, die in gewissem Grade die primären Verhältnisse zwischen den Oxyden veränderte, ist die obenerwähnte Verarmung der Gesteine an SiO_2 and Alkali und die Bereicherung an TiO_2, Oxyden von Fe, Al und Alkalierden (zwei letzteren Quarz betreffend) ganz deutlich aus der Tabelle 2 ersichtlich und die obenerwähnten Betrachtungen über die Ursachen der Magmadifferenziation bestätigend. —

Also kann man annehmen, dass im ABAKANISCHEN QUARZ DIORITMASSIV EINE DIFFERENZIATION NACH DEM GRAVITATIONGESETZ STATTGEFUNDEN HAT UND DER ERZLAGERSTÄTTE INFOLGE VON INTRUSION ABDIFFERENZIERTEN, STARK BEREICHERTEN FE-VERBINDUNGEN EINES TEILES DES MAGMAS IM NEBENGESTEINE GEFÜHRT HAT.

Die geschilderten Erwägungen über die Entstehung der Abakanischen Lagerstätte infolge von Auspressung der Differenziationsprodukte des Quarzdioritmagmas in die Nebengesteine in Betracht ziehend, muss augenscheinlich hieraus erfolgen, dass der Einfallwinkel der Spalten mit Produkten dieser Intrusionen ausgefüllt, ausser beständiger Fallrichtung nach dem Lakkolith, gesetzmässig in seiner Grösse sich verändern muss: in den Gesteinen über dem Scheitel des Lakkoliths muss senkrechtes und steiles Einfallen vorherrschen infolge der Lokalisation des Bassins, aus welchem die Auspressung des Magmas unmittelbar unter der Beobachtungsstelle vor sich ging, und in dem Masse, in welchem die Entfernung von der Projektion des Scheitelpunktes des Lakkoliths an der Oberfläche wächst, muss sich die Grösse des Einfallwinkels im allgemeinen proportionell zu der Entfernung vermindern. —

Ungeachtet der wesentlichen Hindernisse in der Äusserung dieser Gesetzmässigkeit — ungleichartige Bestandteile der Gesteine dieses Bezirkes — kann man zur Zeit der Feldarbeiten diese Erscheinungen genügend deutlich beobachten. —

Im Erz, das in Stöcken gelagert ist und fast in einer Linie sich erstreckt, kann man dieselben Erscheinungen bemerken. — Verringerung des Einfallwinkels des Stockes mit der Entfernung vom Lakkolith und die Übereinstimmung der Fallrichtung dieses Winkels — alle Stöcke fallen in südlicher Richtung ein — das sind Erscheinungen, die die Analogie der Genesis der Erze mit derjenigen der obenerwähnten Differenziationsprodukte bestätigen. —

In einem der Abbaue der Lagerstätte hat Prof. Ussow (12-S. 21) die Einsprengungen von Nebengesteinen in Grösse von ca 4 Mt. Länge beobachtet, alle in vertikaler Richtung lagernd mit undeutlichen Konturen (S. Fig. 3). —

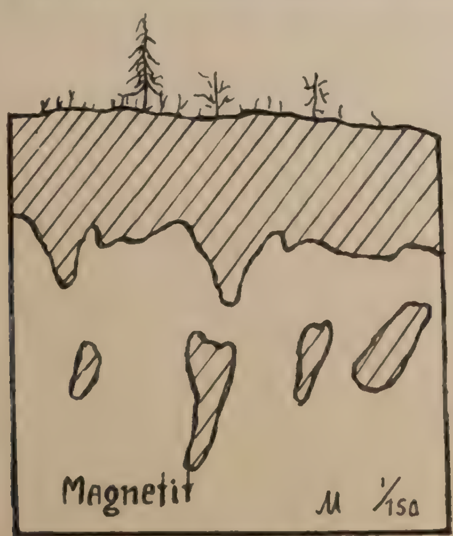

Fig. 3.

Eine solche Orientierung der Blöcke ermöglicht die Erzbildungsbedingungen zu beleuchten, denn die Intrusion des Erzes geschah unter Druck, was eine solche Lagerung der Blöcke aus den Nebengesteinen hervorrief (SPURR 9 S. 330). —

Die mikroskopische Untersuchung zeigt gleichfalls einen stattgefundenen starken Druck, welchem die Gesteine des Lagerstättenrayons unterworfen waren, hierbei zahlreiche Beispiele gebend über starke Deformation der Kristalle des Plagioklases, welche zersplittert, zerbrochen und verbogen sind. —

Pneumatolische und termalische Prozesse waren in der Lagerstätte nur in schwachem Grade erschienen. — Als Folge der ersteren war die Bildung von Apatit, characteristischem, blattförmigem Hämatit nach (0001), was Merkmale seiner Entwickelung infolge gegenseitiger Einwirkung von Fe^2Cl^4 und Wasserdämpfen aufweist (15 s. 311). — Auf gleiche oder vielleicht auf eine spätere Zeit beziehen sich die Ablagerungen von Sulfiden, Cu und Fe. — Alle diese Mineralien lagerten sich in den Spalten des Gesteines über den Erzstöcken und teils in den Stöcken selbst ab. —

Eine gewisse grössere Bedentung hatten die termalischen Prozesse. — Die heissen erzenthaltenden aus dem Magma ausgehenden Wässer haben Magnetit in die Nebengesteine hineingeschwemmt und auf dieselben in metasomatischer Weise einwirkend haben sie grünsteinige Umwandlungen der Erzlagernebengesteine hervorgerufen (Plagioklasporphyrite), unter Bildung in diesen von Chlorit, Epidot, Kaolin mit Ausscheidung von Aktinolith, Quarz und Calcit. — Die Zone dieser eine Umwandlung erlittener Gesteine in Stärke von einigen Metern umschliesst die Erzstöcke. —

Was die Frage über die ähnliche Genesis (weitgehende Differenziation des Magmas nach dem Gravitätsgesetz) der Eisenerzlagerstätte anbelangt, so sind nach Meinung des Autors der Abakanischen am meisten nahestehende Folgende:

1) — Duluth Lakkolith — Minnesota (Differenziationsprodukte — Mikropegmatit, Granit, Syenit, Anorthosit, Gabbro, Norit, FeMgNorit, Pyroxenit, Dunit, Erz (Magnetit). — (13-S. 202, 372; 16 Bd. V s. 978, Bd. IV S. 302 und No. 1-S. 814).—

2) — Bushveld Lakkolith — Transvaal, Differenziationsprodukte — Granit, meisteils mikropegmatitisch, Norit, Gabbro. Pyroxenit, Magnetit und Chromiterz (5-S. 42). —

Die Hauptunterschiede der aufgezählten Lagerstätten von der Abakanischen bestehen darin, dass die Differenziationsprodukte in ihnen in Tiefebedingungen abkühlten, sondern nicht an der Oberfläche, wie es in der Abakanischen der Fall gewesen ist. —

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6. DIFFERENTIATION DER KARROO-ERUPTIVA IM SÜDLICHEN KAOKOFELD, SÜDWESTAFRIKA.

Von E. Reuning, Giessen.

Mit 2 Tabellen und 3 Diagrammen.

INHALT.

(1) *Auftreten und Verbandsverhältnisse der Karroo-Eruptiva.*

In meiner Abhandlung[1]) "Die Entwicklung der Karrooformation im südlichen Kaokofeld, Südwestafrika" habe ich in groben Zügen die Schichtenfolge der Karroosedimente beschrieben und bereits auf die grosse eruptive Tätigkeit während und am Ende des Karroozeitalters hingewiesen.

Der Beginn der Eruptionen liegt im südlichen Kaokofeld in gewissen Gegensatz zu denjenigen im übrigen Südafrika schon im oberen Dwyka. Vulkanische Bombenhaufwerke und Tuffe schichten sich in bunten Wechsel mit sandigen und tonigen Sedimenten und bauen die mehrere hundert Meter hohe Umwallung des grossen Doroskraters auf, der in späteren Verlauf die ausgedehnten und mächtigen Decken des südlichen Kaokofeldes geliefert hat.

[1]) E. Reuning, Die Entwicklung der Karrooformation im südlichen Kaokofeld. Südwestafrika. Neues Jahrbuch für Mineralogie, etc. B.Bd. LII, Abt. B. p. 94-114.

Nach der Ablagerung des Hauptsandsteins, den ich dem Cave Sandstone Südafrikas gleichsetzen möchte, wurden zuerst verhältnismässig basische Laven und zwar Melaphyre (siehe Tabellen, Gesteine Nr. 6 and 7) gefördert. Der Ausbreitung und den Mächtigkeiten entsprechend, müssen diese Laven recht dünnflüssig gewesen sein; die blasige Beschaffenheit der Melaphyre weist auf einen hohen Gasgehalt hin. Ober- und Unterflächen der Decken sind gut zu erkennen, besonders dann, wenn Sande zwischengelagert wurden.

Den unteren Decken blasiger Melaphyre sind 4 mehr oder weniger durchhaltende, wenige Meter mächtige Sandsteinlager zwischengeschaltet, die, trotzdem sie auskeilen und wieder erscheinen, horizontbeständig sind. Auch sind gelegentlich linsenförmige Einschaltungen von Tuffen vorhanden, sie treten sogar noch zwischen hohen Deckenhorizonten auf. Auf den blasigen Melaphyren lagern dichte, glasige, aber immer noch intermediäre Gesteine (Nr. 8 und 9). Sie sind von einer ganzen Serie saurer Gesteine und zwar von Orthoklas-Porphyren (Nr. 10 bis 15) überlagert. Während die Gesamtmächtigkeit der Decken der basischen Effusivphase nur 150-200 m beträgt, erreicht die der sauren Phase bis über 600 m.

Nachdem bereits ein grosser Teil dieser Decken und auch der unterlagernden Sedimente durch Denudation und Erosion abgetragen und beseitigt waren, quollen im Doroskrater in seitlichen Kanälen und in Gängen basische Magmen (Nr. 4 und 5) empor. Nur die Gänge sind bis zu den Niveaus der Porphyre hochgedrungen. Sie sind in der ganzen Küstenregion sehr weit verbreitet, besonders schön sieht man sie in der entblössten Namibfläche, wo sie in langen Zügen den kristallinen Untergrund durchschneiden. Die den Kanälen entstammenden Massen sind meist unter den Melaphyren abgekehrt worden und seitlich ausgeflossen. Sie benutzten die vorhandenen Erosionstäler und haben sich bis in das Huabtal ausgebreitet, wo sie auf kristallinem Untergrund auflagern. Diese Ströme schneiden mitunter durch die ganze Folge der Karroosedimente, und Kontakterscheinungen sind von dem Hauptsandstein bis zum kristallinen Untergrund zu beobachten.

Im Doroskrater stehen basische, grobkörnig entwickelte Gesteine in ringförmiger Anordnung an. Ein äusserer Ring (Nr. 1) besteht aus Olivingabbro, ein zweiter Ring aus olivinarmem Gabbro (Nr. 2), der Kern hat diabasisch struierten Gabbro, der mitunter weniger grobkörnige Schlieren enthält. In diesem Kern setzt ein wenige Dezimeter bis zu 2 m anschwellender Gang und mehrere kleine Gänge eines rosafarbenen Aegirin-Bostonits (Nr. 3) auf.

(2) *Chemismus der Karroo-Eruptiva.*

Die Verschiedenartigkeit der vorerwähnten Eruptivgesteine, die in ihrer Gesamtheit der grossen Epoche der Karrooeruptiva angehören, liess

vermuten, dass für alle diese Gesteine gewisse verwandtschaftliche Beziehungen bestehen und dass irgendwelche Gesetzmässigkeiten bezüglich der Differentiation zu erkennen sind. Ich liess deshalb von Durchschnittsproben, die ich an Ort und Stella selbst entnahm, Analysen anfertigen, die von dem früheren langjährigen Assistenten am Chemischen Universitäts-Institut Giessen, Dr. L. Möser, ausgeführt worden sind. Zur Vergleichung des Chemismus dieser Gesteine versuchte ich mehrere graphische Darstellungsmethoden anzuwenden. Ich entschied mich für die Niggli'sche Darstellungsweise, die den wahren Chemismus voll berücksichtigend, die physikalisch-chemischen und mineralogischen Zusammenhänge voll würdigt und dazu in den Diagrammen eine klare anschauliche Darstellung bringt und eine leichte Vergleichung und Diskussion ermöglicht.

Bei den ersten Eruptionen des Doroskraters, noch während der Periode der Bildung der Kaokosedimente, wurden nur Bombenhaufwerke und Tuffe ausgeworfen. Irgendwelche Ergüsse sind in jener Periode nicht festzustellen. Die Auswürflinge, soweit sie der Tiefe entstammen, gehören zu olivinreichen Melaphyren, etwa zwischen die Gesteine Nr. 1 und 2.

Die Einleitung des ganzen eruptiven Zyklus wird also von basischen Magmen gebildet, die etwa zwischen den hornblendit-pyroxenit-peridotischen und den pyroxenit-hornblendit-gabbroiden Magmen der Kalk-Alkalireihe stehen.

a) *Basische Effusivphase.*

Die untersten Eruptivgesteinsdecken blasiger Melaphyre (Nr. 6 und 7) über dem Hauptsandstein und zwischen den Sandsteinbändern weisen von den hohen Bergen Khuab, Awahuab und Tsuhasis ein schwaches Gefälle nach Norden und Westen auf, und entstammen aller Wahrscheinlichkeit nach dem Doroskrater. Ihr Chemismus stellt sie zu den gabbrodioritischen Magmen der Kalk-Alkalireihe. In den nächst höhergelegenen Decken (Nr. 8 und 9; Nr. 9 gehört dem Maamser Horizont an und steht zwischen Nr. 7 und 8) nimmt die Blasigkeit ab, die Melaphyre werden dichter und feinkörnig-intersertal. Die si-Zahl in Nr. 8 ist etwas höher als der maximale Grenzwert für gabbrodioritische Magmen, ebenso deutet ein höheres k darauf hin, dass dieses Gestein nach den lamprosyenitischen Magmen der Kalireihe neigt. Dies kommt in dem k:mg—und dem mg: c/fm—Diagramm bereits deutlich zum Ausdruck.

b) *Saure Effusivphase.*

Mit dem Gestein Nr. 10, das im Atsab-Profil über Nr. 8 erscheint, hat die Ausstossung von Magmen begonnen, die bis zu den höchsten noch vorhandenen Decken hinauf durchaus porphyrische Gesteine lieferte. Wenn auch in Nr. 10 die Quarzzahl noch unter 100 bleibt und damit einen gewissen Übergang von Nr. 8 zu den Nummern 11 bis 15 zeigt, so dokumentieren doch die hohe si-Zahl, das hohe al und alk und das hohe k einen Chemismus, der die Gesteine Nr. 10—12 zu den normalgranitischen der Kalk-Alkalireihe mit einer Tendenz nach der tasnagranitischen der Kali-

reihe, die Gesteine Nr. 13 und 14 zu den quarzdioritischen der Kalkalkalireihe verweist. Das hohe fm>29 in der Serie Nr. 10—14 lässt noch eine gewisse Verwandtschaft mit den basischen Melaphyr-Magmen erkennen. Bei Nr. 13 ist ein gewisser Rückschlag zu beobachten, alk nimmt zu Gunsten von c etwas ab, ebenso geht k zurück.

In der obersten Porphyrdecke, (Nr. 15), die nur an den hohen Bergen Khuab und Awahab in grösserer Mächtigkeit erhalten geblieben ist, tritt uns, soweit bekannt, der letzte Vertreter der Deckenergüsse entgegen. Dieser Porphyr nimmt eine Zwischenstellung ein zwischen den yosemitischen Gesteinen der Kalkalkalireihe und den rapakiwitischen der Kalireihe. Für erstere ist sein fm. etwas zu hoch, c zu klein, aber fm+c<35, für letztere ist die Differenz al-alk zu gross. Immerhin steht dieser Porphyr am sauren Ende der ganzen Deckenergüsse und fällt in die Gruppe der granitischen Magmen.

c) *Basische Endphase und Doroskrater.*

Die Strommelaphyre der jüngsten Phase (Nr. 4 und 5) sind vollkommen dichte, feinkörnige Gesteine und scheinen mit den Dorosgabbros und den weitverbreiteten sogenannten Gangdiabasen enge Verwandtschaft zu besitzen. Ihr Mineralbestand, ebenso Struktur und Textur entsprechen denjenigen normaler Diabase. Der Chemismus weist sie zu den normalgabbroiden Magmen der Kalkalkalireihe. Diese Strommelaphyre und die sogenannten Gangdiabase, die höchstwahrscheinlich einer ruhigen Effusivphase angehören, erscheinen verhältnismässig spät am Schlusse des ganzen Karroo-Eruptionszyklus.

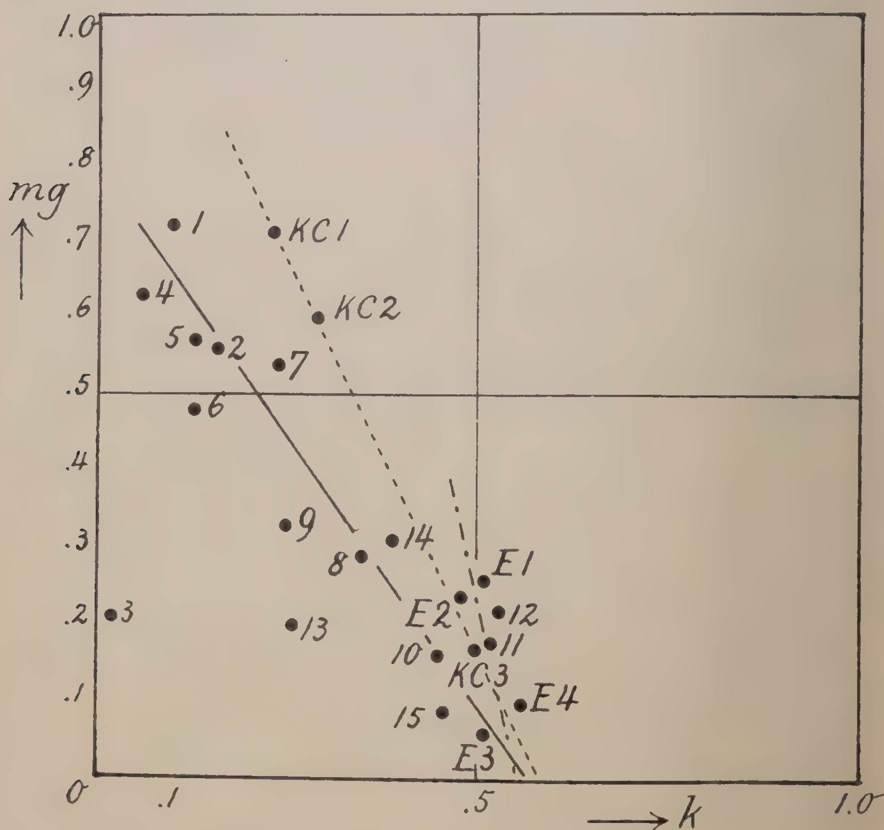
Wir haben nun die Dorosgesteine selbst zu betrachten. Man muss sie als Stielgesteine zu den Tiefengesteinen stellen, obgleich besonders das Kerngestein gelegentlich echt diabasische Texturen zeigt.

Der äussere Ring (Nr. 1) wird von einem Olivingabbro gebildet. An seiner Zusammensetzung nehmen teil: Olivin mit 48%, Augite 20%, Feldspäte 23%, Erze 7%. Seine Niggliwerte weisen es eindeutig zu den hornblendit-pyroxenit-peridotischen Magmen der Kalkalkalireihe.

Der zweite Ring (Nr. 2) unterscheidet sich von dem äusseren Ring schon im Felde durch ziemlich scharfe Abgrenzung und durch seine pockennarbige Verwitterung, besonders aber mineralisch und chemisch. Olivin ist nur noch mit 12%, Augite mit 22%, Feldspäte sind mit 55% und Erze mit 10% beteiligt. Dieser Gabbro ist trotzdem al<20 zu den pyroxenit-hornblendit-gabbroiden Magmen der Kalkalkalireihe zu stellen. Das Kerngestein gleicht in seinem Mineralbestand und Chemismus den Strommelaphyren. Es ist in seinen mittleren Teilen überaus schlierig und hier auf diesen Schlieren sind ganz zum Schlusse Ganggesteine von geringer Ausdehnung und Mächtigkeit ausgequetscht worden, die hauptsächlich aus einem perthitischen Anorthoklas mit durchspiessenden zonar gebauten Aegirin — (bezw. Akmit) — nadeln bestehen. Der hohe Natrongehalt ist, bei hohem al und einem mässigen Gehalt an c zur Bildung von perthi-

tischem Anorthoklas verwendet worden, ein Natronüberschuss ging in die Augite ein. Die Textur ist hypidiomorph-körnig und lässt die Deutung zu, dass dieser Aegirinbostonit noch vor vollendeter Abkühlung des Kerngesteins ausgepresst worden ist. Dem Chemismus nach gehört er zu den natronsyenitischen Magmen der Natronreihe.

k:mg-Diagramm.



d) *Magmenfolge*:

Ueberblicken wir nochmals den ganzen Zyklus, so finden wir manche Analogien mit anderen Eruptions — bezw. Intrusionszentren. Zu Beginn haben wir ganz basische Magmen, die in ihren letzten Vertretern schon eine Differentiation erkennen lassen, die später in den Porphyren voll zum Ausdruck gelangt. Auf die Phase der nächsten Porphyre folgt eine Ruheperiode, nach der wiederum basische Magmen, chemisch ähnlich den ersten, ausgestossen werden, aber die Effusivkraft reicht nicht mehr aus, um sie in grosse Höhen zu befördern. Quantitativ steht diese Strom- und Gangphase hinter der basischen ersten und sauren zweiten Phase zurück.

Den Abschluss bildet ein Natrongestein, das nur in ein paar schwachen

Gängen im Kerngestein aufsetzt. Seine Erscheinung ist eigenartig und kann wohl verursacht worden sein durch Wechselwirkung zwischen dolomitischen Kalken, die dem alten Gebirge angehören und auch in den Kalkbombenhaufwerken herausbefördert worden sind und Abfolgen des granitischen Magmas der Porphyrphase.

Mit Ausnahme dieses Aegirinbostonits gehören alle Effusionen der Kalkalkalireihe an, gelegentlich zeigen sich Neigungen zur Kalireihe. Gesteine der atlantischen (Natron-) Sippe liegen in den Karrooeruptiva des südlichen Kaokofeldes nicht vor.

3) *Eruptiva der weitern Umgebung.*

a) Aus der Gegend von Cap Cross wurden mehrere Gesteine untersucht. Die beiden KC1 und KC2 zeigen nahe Verwandtschaft zu einander und zu den Strommelaphyren, KC1 gehört einem Stiel oder bauchigen Gang an. Komplementär dazu steht KC3, ein granitisches Gestein, das wahrscheinlich in kleinen stielförmigen Intrusionen die deckenartig ausgebreiteten Melaphyr KC2 durchsetzt. Alle 3 Gesteine gehören den Kalkalkalimagmen an.

b) Die Gesteine des Erongo, die von H. Cloos* ausführlich beschrieben worden sind, sollen bezüglich ihres Chemismus hier ebenfalls kurz diskutiert werden. Der Erongo-Melaphyr E1 stellt sich nahe an die Seite von Nr. 8. Sein hohes k rückt ihn aber von den normaldioritischen Magmen nach der Seite der lamprosommaitischen Magmen der Kalireihe. Der Granodiorit E2 kommt Nr. 12 bezw. Nr. 11 am nächsten und gehört zu den tasnagranitischen mit Uebergang zu den syenitgranitischen Magmen der Kalireihe. Im Erongo bildet der Quarzporphyr E3 die höchste Decke. Er zeigt eine nahe Verwandtschaft mit den Orthoklas-Porphyren der höchsten Decke am Khuab, ist nur noch kalireicher, wodurch er den rapakiwitischen Magmen zugerechnet werden muss.

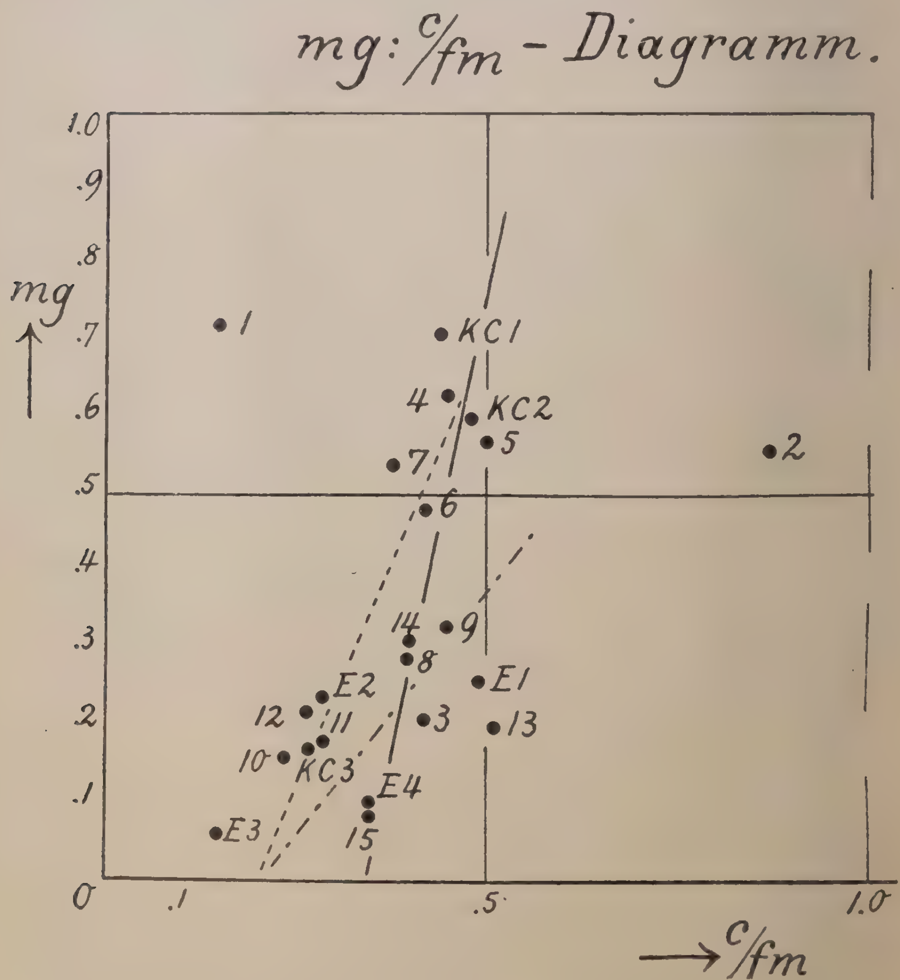
Der Erongogranit E4, der nach den Untersuchungen von H. Cloos einen Aufbruch jünger als die Erongosedimente und Melaphyre darstellt.**

*) H. Cloos, Der Erongo, Beiträge zur geologischen Erforschung der deutschen Schutzgebiete. Heft 17, Berlin, 1919.

**) Anmerkung: Am Brandberg lagern Karroosedimente mit den daraufliegenden Melaphyren auf zersetztem alten Granit. Mit diesem hielt ich den domförmig abgesonderten Granit des inneren Berges für ungefähr gleichalt bezw. nur wenig jünger, aber derselben Intrusiveperiode zugehörig. Die neuesten Untersuchungsergebnisse von H. Cloos haben mich nun überzeugt, dass der Granit des Brandberginnern, ebenso auch die Domgranite von Spitzkopje und andere in der nördlichen Namib von Südwestafrika auftretende Domgranite einem sehr jungen Eruptionszyklus angehören und damit auch die Zweifel behoben, die ich bezüglich der Stellung des Erongogranits hegte. Ich bin Herrn Cloos für seine Mitteilungen äusserst dankbar, ebenso Herrn Gevers, der das jüngere Alter des Granits von Spitzkopje bestätigte. Das Bild, das wir uns von dem gesamten Karrooeruptionszyklus im Norden von Südwestafrika entwerfen können, wird jetzt sehr viel anschaulicher und lässt die lateralen und temporalen Verbände zwangslos erklären.

Capetown, September, 1929. E.Rg.

muss als das mit den sauren Porphyren eng verknüpfte Tiefengestein angesprochen werden. Er steht dem jüngeren Granit von Cap Cross sehr nahe, ist nur kalireicher und neigt daher noch mehr den rapakiwitischen Magmen der Kalireihe zu. Da diese Granite jünger sind als die Melaphyre, so muss ihnen zumindest ein oberkarrooisches (Stormberg-) Alter zugeschrieben werden. Somit gehören sie zu den jüngsten bekannten Graniten.



4) *Beziehungen der Gesteinsreihen zu einander.*

Vergleicht man nun die Kaokoeruptiva mit den Gesteinen von Cap Cross und dem Erongo, so findet man manche gemeinsamen Merkmale. Ich habe in meiner Abhandlung "Die Entwicklung der Karrooformation im südlichen Kaokofeld" bereits mitgeteilt, dass die Sedimente und Eruptivdecken am Brandberg, im Gobobosib-Bergland, bei Cap Cross und Otjongundu und am Erongo gleichalterig sind mit denen im südlichen Kaokofeld.

Die sedimentären Ablagerungen lassen eine Uebereinstimmung erkennen und auch hinsichtlich der Eruptiva zeigen sich enge Beziehungen in dem Chemismus, in der Differentiation und der Erscheinungsfolge der Magmen. Neben dieser nahen Verwandtschaft der Kaoko-Cap Cross- und Erongogesteine kann man aber auch geringe Verschiedenheiten feststellen, die uns trotz der verhältnismässig wenigen Analysen doch schon einige Schlüsse über Differentiationsverlauf und Ursprung zu ziehen gestatten. Einmal liegt bei einem nahezu parallelen Verlauf der Verbindungslinie der entsprechenden Projektionspunkte im Differentiationsdiagramm, die Isofolie der Kaokoeruptiva bei etwa 316, die der Erongogesteine bei 251 (die Isofalie der Cap Cross-Gesteine ist unsicher). Im k : mg—-Diagramm weisen die Mittellinien der Projektionspunkte der Gesteine der drei Reihen unterschiedliche Richtungen auf, und ebenso weichen auch die Mittellinien im mg : c/fm Diagramm von einander ab. Das spricht entweder für eine wenig von einander abweichende provinzielle Differentiation oder für etwas von einander verschiedene Ursprungsmagmen, oder für beides in Verbindung miteinander und findet eine gewisse Bestätigung in den getrennt liegenden Ausbruchszentren, die durch die geologischen Untersuchungen festgestellt worden sind.

TABELLE 1.
KAOKO-ERUPTIVA, ANALYSENRESULTATE.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	KC1	KC2	KC3
SiO_2	42·64	48·42	62·75	46·16	47·56	50·87	53·48	56·13	55·59	67·79	67·27	66·27	65·25	66·38	68·18	49·70	50·65	73·42
TiO_2	1·30	2·40	·70	·83	1·34	1·72	2·48	1·67	1·89	1·00	1·14	1·11	1·18	·97	·97	·36	·91	·52
Al_2O_3	5·68	14·24	15·75	15·02	14·82	16·63	9·24	13·17	11·23	10·77	12·07	11·93	11·98	12·32	15·08	17·15	16·04	13·14
Fe_2O_3	4·87	3·84	6·98	3·96	2·70	8·33	9·28	7·79	10·32	6·81	6·25	7·16	6·58	2·24	5·20	2·37	8·08	2·26
FeO	12·02	5·66	·43	7·77	9·50	2·77	2·61	5·09	3·66	·78	1·30	1·22	1·65	4·54	·22	6·19	2·83	·52
MnO	·21	·15	·08	·14	·07	·07	·18	·10	·12	·10	·12	·08	·08	·07	·12	·16	·12	·03
MgO	23·17	6·48	·99	10·79	8·83	5·29	7·24	2·77	3·56	·76	·82	1·24	1·02	1·65	·28	11·42	8·71	·28
CaO	6·93	13·95	2·78	11·03	10·86	6·30	7·30	5·28	6·97	1·64	2·01	2·11	3·83	2·95	1·59	9·85	9·63	·75
Na_2O	1·63	3·25	8·06	2·12	2·52	4·37	2·18	2·68	2·47	3·64	2·49	2·29	2·84	2·85	3·04	1·46	1·46	3·24
K_2O	·25	·96	·25	·20	·57	1·00	·99	2·12	1·22	4·55	4·06	3·92	1·62	2·74	3·97	·65	·98	4·99
H_2O+	·63	·77	·61	1·53	·88	1·84	2·12	2·00	1·49	1·37	1·29	1·29	3·04	2·60	1·52	·75	·60	·72
H_2O-	·05	·05	·35	·20	·25	·64	2·88	·83	1·09	·44	·67	·97	·80	·14	·05	·26	·10	·29
P_2O_5	·22	·10	·08	·16	·18	·24	·24	·23	·26	·18	·25	·29	·24	·22	·23	sp.	·04	·09
CO_2	·08	·08	·14	·32	·25	—	—	·55	—	—	—	—	—	—	—	—	sp.	—
S	—		—	—	—	·08	—	—	—	—	—	—	—	—	—	—	—	—
CuO	—	·02	·06	·02	·02	·04	·11	·06	·06	·02	0·2	·02	·07	·05	·02	·06	·05	·04
	99·68	100·37	100·01	100·25	100·35	100·19	100·33	100·47	99·93	99·85	99·76	99·90	100·18	99·72	100·47	100·38	100·20	100·29

Sämtliche Analysen wurden von Dr. L. Möser, Giessen gefertigt.

7. DIFFERENTIATIONEN UND DIFFERENTIATIONSPROBLEME SÜDAFRIKANISCHER GESTEINSMAGMEN.

Von E. Reuning,
Giessen.

Mit einer Tabelle und 4 Diagrammen.

Die grosse Anzahl südafrikanischer Eruptivgesteinstypen und die Fülle gleichartiger, zum grossen Teil fast übereinstimmender, zum Teil aber auch stark voneinander abweichender Gesteine liess es mir wünschenswert erscheinen, die chemischen Verhältnisse einer Untersuchung zu unterziehen. Hierzu angeregt wurde ich besonders durch die Ergebnisse einer Betrachtung des Chemimus der Gesteine des Bushveld Igneous Complex, die im Neuen Jahrbuch für Mineralogie 1927 B. Band LVII, Abt. A, Seite 631-664 veröffentlicht worden sind.

Es galt für mich an Hand von Analysen südafrikanischer Gesteine herauszufinden, ob wir an dem grossen Komplex so sehr verschiedenartiger Gesteine gewisse Gesetzmässigkeiten in den Differentiationsverläufen erkennen können, und ob wir dadurch zu irgendwelchen Rückschlüssen gelangen. Die von Niggli empfohlene Darstellungsweise des Chemismus gesteinsmässiger Mineralassoziationen, die ich selbst wiederholt benutzt habe, schien mir einen Vergleich am übersichtlichsten zu gestalten. Sie wurde deshalb auch bei diesen Untersuchungen angewandt. Die in der mir zugänglichen Literatur vorhandenen Analysen — soweit sie als vollständig zu betrachten sind — wurden unter Benutzung der H. Eckermann'schen Tabellen berechnet, und die gewonnenen Zahlenwerte in Diagramme eingetragen.§

I. *Gesteine des Normalfalles der Differentiation.*

Leider sind nur wenige Analysen vorhanden von alten gabbroiden Tiefengesteinen und den alten Graniten, sowie ihren Zwischengliedern, ebenso fehlen auch Analysen von alten Intrusiv—und Effusivgesteinen und metamorphosierten Eruptivgesteinen. Das kommt wohl hauptsächlich dadurch, dass sie eben nichts Abweichendes von diesen weltweitverbreiteten Typen zeigen. Man hat mehr die abnormen Gesteine und Varietäten behandelt. Dennoch tritt ganz deutlich in Erscheinung, dass die normale Differentiationsreihe der Kälkalkaligesteine auch in Südafrika den ganzen Komplex intrusiver und extrusiver Erscheinungsformen unterlagert, und lie weitaus grösste Verbreitung besitzt sowohl in den Tiefengesteinen als auch in den Erguss- und Ganggesteinen und besonders in den metamorphen Gesteinen alter eruptiver Zyklen. Diese Tatsache spricht doch dafür, dass der sogenannte normale Fall der Differentiation der allgemein herrschende ist, bezw. in den älteren geologischen Epochen der fast allein herrschende war. Erst in jüngeren Epochen zeigen sich Varianten.

Die basischen Glieder sind vertreten durch ein paar Gabbros und Diorite, hauptsächlich aber durch- Erguss- und Ganggesteine und zwar durch Diabase und Melaphyre. Unter den si-armen und si-reicheren sauren Gliedern finden wir reine Kalkalkali-Granite, Felsite, Quarzporphyrite, Andesite, Rhyolite u.s.w.

§) Zur Zeit der Ausarbeitung dieser Diagramme war ich leider noch nicht im Besitz der von R. A. Daly in seiner Abhandlung "Bushveld Igneous Complex of the Transvaal" (Bulletin of the Geological Society of America, Vol. 39, p. 703-768, 1928) mitgeteilten Analysenresultate. Sie sind mir erst kürzlich (April. 1929) durch Professor Shand zugänglich geworden. Ihre Niggliwerte wurden nachträglich in die ausgezeichneten Diagramme eingetragen.

Die Porphyre des Kaokofeldes und des Erongo*) sind neuerdings von mir abgehandelt worden. Sie passen sich dem Normalfall der Differentiation vollkommen ein, und dies kommt auch in den Diagrammen klar zum Ausdruck.

II. *Sonderfälle der Differentiation.*

Betrachten wir nun alle übrigen südafrikanischen Gesteine innerhalb ihrer geologischen Verbände, so fällt uns auf, dass sie ausserhalb des Normalfalles der Differentiation stehen und extreme Sonderstellungen einnehmen.

1) Bushveld Igneous Complex:

a) Norite, Pyroxenite, Dunite.

Die eigenartig verlaufenden Kurvenstücke im Differentiationsdiagramm für die al—, fm —,c—, und alk-Werte und die Lage der Projektionspunkte im k:mg — und mg:c/fm—Diagramm sprechen dafür, dass die Norite, Pyroxenite und Dunite selbständigen Teilmagmen angehören, die bereits vor ihrer Intrusion an ihren jetzigen Ort bestanden haben müssen. Uebergänge sind nicht vorhanden und nach den Kurvenverläufen auch ausgeschlossen. In den letzten beiden Diagrammen bewegen sich die Projektionspunkte der den 3 Gruppen angehörenden Gesteine innerhalb eng begrenzter, getrennt liegender Projektionsfelder. Dennoch aber ist zwischen Pyroxeniten und Duniten eine gewisse Verwandtschaft ersichtlich und sie zeigt sich auch in ihrem Zusammenauftreten in den sogenannten Dunitkopjen. Die Norite stehen ziemlich abseits beider, sie haben auch nur wenige verwandte Merkmale mit den überlagernden jüngeren Granophyren und Graniten. Die von Daly mitgeteilten neuen Analysen von Pyroxeniten und Noriten stimmen hiermit vollkommen überein, auf Abweichungen komme ich noch zurück. Verhältnismässig enge Beziehungen bestehen auch hinsichtlich des Chemismus der pegmatitischen und anorthositischen Norite mit den eigentlichen Noriten.

b) Chromite und Magnetite.

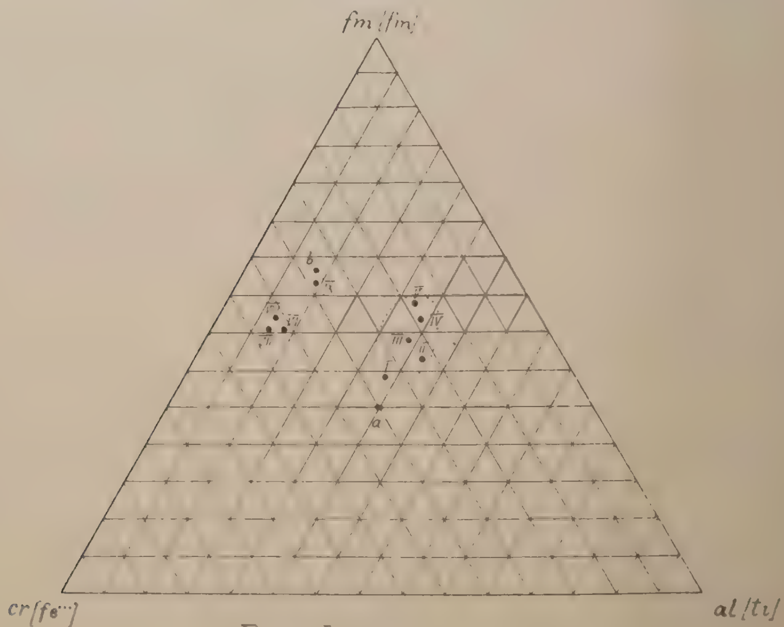
Die in dem untern Noritkuchen auftretenden Chromerzlager, die Magnetitlager und weiten gangförmigen Aufbrüche nehmen Extremstellungen ein, wenngleich ihre Zugehörigkeit zu dem Noritkuchen aus den Verbandsverhältnissen klar hervorzugehen scheint. Im Differentiationsdiagramm stehen sie am si-ärmsten Ende. Eine projektive Darstellung in dem k:mg und dem mg:c/fm—Diagramm war nicht möglich, da die von Daly mitgeteilten Analysen nicht vollständig sind. Diesen Punkt werde ich später

*) E. Reuning, Differentiation der Karroo-Eruptiva im südlichen Kaokofeld, Südwestafrika. Siehe diesen Band Abhandl. No. 6

noch besprechen. Um diese Erze jedoch miteinander vergleichen zu können habe ich bei den Chromiten die nach Niggli berechneten Werte für fm, cr und al bezw. bei den Magnetiten für fm, fe''' und ti auf die Summe 30 reduziert, ebenso die der theoretischen Erzgehalte und die erhaltenen Neuwerte in einem Dreiecksdiagramm eingetragen.

c) Uppermost norites.

Wenn wir nun die Niggliwerte der von Daly mitgeteilten Analysen der 3 zu den "uppermost norites" gehörenden Gesteine mit denen der Norite vergleichen, so stehen wir vor einer klaffenden Lücke. Die 3 Gesteine besitzen unter sich durchaus verwandte Merkmale, aber ihrem Chemismus nach kann man sie unmöglich zu den Noriten rechnen. Im Differentiationsdiagramm nehmen sie eine Sonderstellung ein. Eine Isofalie würde extrapolierend etwa bei si=250 zu erwarten sein. Noch deutlicher tritt die Sonderstellung in den beiden anderen Diagrammen in Erscheinung, wo ihre Projektionspunkte in bezw. nahe den Projektionsfeldern der Foyaite und Granite liegen. Ihr Durchschnitt mit si=203, al=26, fm=37, c=19, alk=18, k=0,34, mg=0,07, ti=3,1, c/fm=0,50 weist sie mehr den si-armen Gliedern der Granite zu (Neigung nach opdalitischen Magmen.) Wahrscheinlich haben wir bei diesen Gesteinen Reaktionen der überlagernden sauren granitischen Magmen mit den oberen Zonen der Norite anzunehmen. Hierfür spricht auch die Hornblende, die den echten Noriten fehlt.



Erz-Diagramm.
Nr. I–V Chromite, Nr. VI–IX Magnetite(1).

d) Granophyre und Granite.

Die dem oberen Bushveld-Kuchen angehörenden Granophyre, roten Granite und Felsite bilden eine wohl charakterisierte Gruppe von sauren granitischen Magmen, die wegen ihres etwas höheren fm-Gehaltes in ihrer Gesamtheit am besten den engadinitischen Magmen zugerechnet werden können. Die si-Zahl schwankt zwar zwischen 369 und 485, doch halten sich die übrigen Werte in engen Grenzen. Die von mir früher erwähnten Gesteine (Rg 51, 54 und 55) stehen mit einem durchschnittlichen si=334, al=34, fm=28, c=9, alk=29, k=0, 54 und mg=0, 35 an dem si-ärmeren Ende der Gruppe. In dem k: mg Diagramm fallen die Projektionswerte der Gesteine dieser Gruppe innerhalb des granitischen, im mg: c/fm Diagramm greifen sie auf das foyaitische Projektionsfeld über. Die von Daly zum Vergleich aufgeführten Durchschnitte von 40 Rhyoliten und 24 Lipariten und von 546 Graniten stehen mit ihren Projektionswerten ebenso wie die der Norite weiter abseits als die am meisten abweichenden Gesteine der entsprechenden Gruppe selbst.

e) Einige andere Gesteine.

Die beiden silifizierten Felsite (Nr. Da 9 und 10) mit einem durchschnittlichen al=38, fm=33, c=6, alk=23, k=0,37, m=0,52 und c/fm =0, 18 nehmen, wie auch aus dem Diagramm ersichtlich ist, eine Sonderstellung ein; sie sind wahrscheinlich durch eine erhebliche Stoffzufuhr umgewandelte Gesteine.

Die als Hornblende-Quarz Syenit (Da 30) und Hornblende-Augit Syenit (Da 31) bezeichneten Gesteine dokumentieren bei einem sehr ähnlichen Chemismus, der den opdalitischen, also si-ärmeren granitischen Magmen nahe kommt, eine enge Verwandtschaft mit den 3 von Daly zu den "uppermost norites" gerechneten Gesteinen.

Im Anschluss hieran seien noch ein Soda-trachyandesit (Da 11) und zwei Hornblende Akerite (Da 12 und 13) erwähnt. Sie stellen höchstwahrscheinlich besondere Differentiate dar ähnlich den Foyaiten, denen sie auch bezüglich ihrer Projektionswerte am nächsten stehen.

Ich habe früher schon darauf hingewiesen, dass eine Berechnung und Projektion der Analysen von Sedimenten, die im Kontakt mit Eruptiva verändert worden sind, vielfach die Art und den Grad der Beeinflussung erkennen lassen. Dies findet eine weitere Bestätigung an den feldspatisierten Quarziten (Da 36, 37 und 38.) Ihre Molekularwerte stehen denen der granitischen Gesteine sehr nahe, was besonders im k: mg-Diagramm zum Ausdruck gelangt, wo die Projektionspunkte dieser stark feldspatisierten Quarzite (Da 37 und 38) im Projektionsfeld der Granite liegen.

f) Der lagerförmige Aufbau der Bushveld-Gesteine.

Ich habe früher bereits die Ansicht vertreten, dass die Differentiation, die zu so verschiedenen wohlumgrenzten Magmen geführt hat, nicht am heutigen Verlagerungsort, sondern vor den Intrusionen hierhin in grösseren

Tiefen stattgefunden haben muss. Eine Differentiation *in situ* halte ich also bezüglich der grossen Massen der verschiedenartigen Gesteine des Noritkuchens für ausgeschlossen, und sie bereitet der Erklärung vieler Erscheinungen allergrösste Verlegenheit. Nehmen wir aber getrennt erfolgte Schübe aus den tiefgelegenen Reservoiren an, die sich in dünnen Lagern stets zwischen den schon vorhandenen und dem Dach einschoben, so begegnen wir kaum noch Deutungsschwierigkeiten, besonders dann nicht, wenn wir eine Wiederholung solcher Schübe aus demselben Magmenreservoir zugestehen. Innerhalb der an Ort und Stelle gelangten Magmen kann dann eine mehr oder minder stark ausgeprägte gravitative Kristallisations-Differentiation zu Variationen geführt haben, wobei der stets gleichsinnig gerichteten Saigerung entsprechende Gesteine entstanden.*)

g) Differentiationsproblem.

Bei Betrachtung des Chemismus der einzelnen Gesteinstypen innerhalb des ganzen Komplexes führt uns das Differentiationsdiagramm Kurvenverläufe vor Augen, die mit einer normalen Differentiation nichts gemeinsam haben können. Das lässt uns vermuten, dass in den Gesteinen des sogenannten Norit- und Granitkuchens eine abnorme Differentiation vorliegt, ähnlich wie wir sie später noch bei den foyaitischen Gesteinen kennen lernen werden. Der hohe Kalkgehalt der noritischen Gesteine bei niederem Alkali in Verbindung mit einem hohen Magnesium- und Eisengehalt machen es wahrscheinlich, dass durch eine in grossen Tiefen stattgehabte Einschmelzung kalkreicher bezw. dolomitischer Sedimente ein neues Magma gebildet (und auch aktiviert) wurde, das sich vor seinem Emporsteigen differenzierte in c-reiche, an Mg und Na verhältnismässig angereicherte basische Magmen und in al- und k-reiche saure Magmen. Eine solche Differentiation ist zu verstehen, wenn man den chemischen Antagonismus von Ca+Na zu K würdigt. Man muss sich dabei vergegenwärtigen, dass im normalen Verband unter den Pretoriaschichten, deren Mächtigkeit im Durchschnitt auf über 3000 m geschätzt wird, die 400-500 m mächtige Dolomitserie lagert, dass fernerhin Magmen von diabasischer als auch granitischer Zusammensetzung das ganze Bushveld-Areal unterlagert haben

*) Anmerkung: Ein treffliches Beispiel liefern die Magnetitlager, die mit den Uebergängen zu dem darüber anstehenden Anorthosit einschliesslich desselben einem Schub angehört haben müssen. Das intrudierte Feldspat-Magnetitmagma hat infolge gravitativer Saigerung die Magnetite nach unten regnen lassen, die oberste Lage wurde fast magnetitfrei, die unterste fast feldspatfrei, dazwischen sind alle Uebergänge von dem einen Extrem ins andere vorhanden. Bei den Pyroxenitlagern (besonders am Merenskyreef) kann man ähnliche Saigerung feststellen, und selbst bei den Noriten beobachtet man sie, nur nicht so ausgesprochen deutlich. Stets aber haben die am Verlagerungsort auskristallisierte und verfestigten Schübe eine anorthositische obere Lage, die nach unten in allmählichem Uebergang zu einem spezifisch schwereren Gestein führt, auf welcher aber durch scharfen Kontakt getrennt der nächst höhere Schub auflagert. (Capetown im Sept., 1929. E.Rg.).

bezw. in älteren Epochen emporgedrungen sind. In den alten, sowohl basischen als auch sauren Intrusionen, finden wir manche gemeinsamen Merkmale, und der normale Differentiationsverlauf war der allein herrschende. In den jüngeren Bushveld-Intrusionen tritt uns nun eine Differentiation entgegen, deren Produkte andere verwandte Merkmale aufweisen, die jedoch vom normalen Fall auffallend stark abweicht. Diese Abweichung lediglich durch andere physikalische Verhältnisse erklären zu wollen, dürfte auf allergrösste Schwierigkeiten stossen.

Das gebildete Ausgangsmagma muss, entweder von Haus aus oder durch die assimilierten Sedimente, sehr reich an Fe und Cr gewesen sein. Beide sind nicht oder nur teilweise in den Verband der sich bildenden Gesteinsmagmen aufgenommen, im übrigen aber als selbständige Oxydmagmen gesaigert worden.

Aehnlich steht es mit den basischen Duniten und Pyroxeniten mit ihrem hohen Fe-und Mg-Gehalt; sie sind gleichfalls als Rest- oder Bodensatzmagmen aufzufassen. Mit dem Dunit gingen Platinmetalle, im Pyroxenit entmischte sich ein an Ni reiches, Platinmetalle führendes Sulfidmagma, das zur Saigerung nicht mehr gelangte und das sich, soweit es nicht in spätere Phasen eintrat, zwischen den auskristallisierenden Gesteinsgemengteilen ausscheiden konnte.

2) Pilansberg.

Die Pilansberggesteine, die von vielen Autoren als letzte Phase des Bushveld Igneous Complex betrachtet werden, sind von Shand*) eingehend beschrieben worden. In den 3 Diagrammen tritt klar in Erscheinung, dass sie trotz ihrer oft von Dezimeter zu Dezimeter hervortretenden Verschiedenartigkeit eine engverwandte Gesteinssippe darstellen. In dem Differentiationsdiagramm jedoch finden wir wieder den einem normalen Differentiationsverlauf nicht entsprechenden, krummlinigen Kurvenverlauf, besonders bei den si-armen Gliedern. Auch liegt die extrapolierte Isofalie etwa bei si=140.

Diese Eigentümlichkeit scheint wieder dafür zu sprechen, dass die Differentiation in ihrer Gesamtheit annormal verlaufen ist, dass sie in den si-armen jüngeren Gliedern weniger ausgereift ist, als bei den si-reicheren älteren. Die Altersfolge der Pilansberggesteine ist nach Shand: Sh I, X; Sh IX (V); Sh VIII, VII, VI. Von dem Gestein Sh V, das eine Ausnahme bildet, abgesehen, finden wir mit abnehmender Altersfolge eine Abnahme an si, al und alk und eine Zunahme an fm und c, eine Beobachtung, die Shand schon auf S.152 seiner Abhandlung klar hervorhebt. Die Ursache dieser fast widersinnig zu bezeichnenden Differentiation fasst Shand in wenig

*) S. J. Shand, The Geology of Pilansberg in the Western Transvaal: A Study of Alkaline Rocks and Ring-Intrusions. Trans. Geol. Soc. of S.A. Vol. XXXI, 1928.

Worten zusammen. Er stellt sich vor, "that after the emplacement of the norite and the red granite there was an unconsolidated residue of granitic magma trapped in the depth, about the base of the Transvaal System; that this residual magma, rich in fugitive constituents as granitic residues always are, reacted with the thick limestones at the base of the system, giving rise to local accumulations of highly alkaline magma; and that the development of faults across the main complex gave an opportunity for this differentiated magma to ascend, forming dykes, plugs and sheets." Ich kann meine aus der Vergleichung des Chemismus der Pilansberggesteine gewonnene Ansicht nicht in bessere Worte kleiden. Bereits bei den Noriten kam ich zu einem gleichen Ergebnis, dass wir es mit einem durch Einschmelzung von dolomitischen Kalken beeinflussten annormalen Differentiationsverlauf zu tun haben; die alte vorgezeichnete Differentiations-Tendenz ist also in der letzten Bushveld Phase nochmals in Erscheinung getreten.

Der von Kaiser in seinem Werk "Die Diamantenwüste Südwestafrikas" mitgeteilte Eläolithsyenit vom Granitberg stimmt mit seinen Projektionen ungefähr mit den sauren Gliedern des Pilansberg überein; im mg: c/fm — Diagramm fällt die Projektion etwas ausserhalb des Foyaitfeldes, was mir auf andere provinzielle Eigentümlichkeiten hinzuweisen scheint.

III. *Kimberlite und Melilithbasalte.*

Der Vollständigkeit halber möchte ich noch 2 weitere wichtige südafrikanische Gesteinsgruppen, die Kimberlite und die ihnen nahestehenden Melilithbasalte, in den Kreis dieser Betrachtungen ziehen. Beide Gruppen stellen sich in den Diagrammen als wohlumschlossene Einheiten dar. Die Kimberlite besitzen durchweg einen sehr gut übereinstimmenden Chemismus. Das für solche basischen Gesteine recht hohe k verweist sie zu den Kaligesteinen, wo sie am besten zu einem besonderen Kimberlit-Typus vereinigt werden sollten mit den Durchschnittswerten si=53, al=3, fm=84, c=11, alk=2, k=0, 70, mg=0, 86, ti=2, 0, c/fm=0, 13; Schnitt II.

Im Einzelnen lassen sich bei den südafrikanischen Kimberliten enige von P. A. Wagner in seinem Buch "The Diamond Fields of S.A.", 1914 schon hervorgehobene Untergruppen auch in den Diagrammen deutlich unterscheiden. Die Kimberleygruppe ist am basischsten, die Pretoriagruppe am sauersten. Die Driekopjes Gruppe steht ungefähr in der Mitte, sie hat aber die höchste k-Zahl, nämlich 0, 89, der Kimberlit von Koffeefontein hat das grösste fm=93 und mg=0, 91.

Die Kimberlite stellen Extremdifferentiate dar mit einem auffallend hohen k-Wert, der nur von einigen Leucitgesteinen übertroffen wird. Von den Kimberliten unterscheiden sich die Melilithbasalte in manchen Punkten recht wesentlich. Die Durchschnittswerte der 4 mitgeteilten Analysen sind:

si=65, al=12, fm=53, c=28, alk=7; k=0, 29, mg=0, 66, ti=3, 1, c/fm=0, 55 Schnitt IV. Es sind also bei den Melilithbasalten al, c und alk wesentlich höher, fm bedeutend niedriger als bei den Kimberliten. Das niedere k mit 0, 29 stellt die Melilithbasalte zu den theralithgabbroiden Magmen der Natronreihe. Sie haben im grossen Ganzen nur wenig verwandte Merkmale mit den Kimberliten, sodass man sie als besondere Differentiate betrachten muss, die wahrscheinlich aber demselben Eruptionszyklus angehören. Sie stehen geologisch und zeitlich in gewisser Beziehung zu einander. Das Nebeneinander beider Gesteine, das im Sutherland Distrikt†) zuerst festgestellt worden ist, hat eine weitere Verbreitung, als bisher angenommen wurde. Dabei liegen die Melilithbasalte mehr in den peripheren Zonen dieser magmatischen Provinzen. Recht eigenartig ist auch ihr ähnliches Vorkommen in Explosionsröhren und ihre bisweilen tuffbrekzienartige Ausbildung. Wahrscheinlich sind die Melilithbasalte wenig jünger als die Kimberlite, und es ist nicht von der Hand zu weisen, dass die Melilithbasalte möglicherweise sogar den Kimberliten nachgedrungen sind, sie gelegentlich herausgedrückt und ihren Platz eingenommen haben.

IV. *Gesteinsprojektion in Beziehung zur Probenahme und Analyse.*

Die von Niggli empfohlene Berechnung von Gesteins-analysen und die Darstellung der Molekularwerte und molekularen Verhältnisse in übersichtlichen Diagrammen lässt uns leicht die gemeinsamen und trennenden Merkmale im Gesteinschemismus erkennen und miteinander vergleichen. Daneben aber gibt diese Methode auch ein brauchbares Kriterium ab für die Entnahme der Proben und für die Verlässlichkeit der Analysen. Man findet gelegentlich, dass einige Gesteinsprojektionen aus dem ihrer Gruppe zustehenden Projektionsfeld herausfallen, trotzdem man dies nicht erwarten sollte. Bei kritischer Auswertung der molekularen Verhältnisse und der diagrammatischen Darstellung der Gesteine gelangt man bei der weitaus grössten Anzahl aller sogenannten unstimmigen Fälle zu den sie hervorrufenden Ursachen. Diese können begründet sein in zweierlei Fehlern: a) einmal bei der Probenahme und dann; b) in der Analyse selbst.

a) Bei der Entnahme von Gesteinsproben sollte man dieselbe Vorsicht walten lassen wie bei der Ziehung von Erzproben. Sie sollen dem Durchschnitt des zu untersuchenden Gesteins entsprechen. Vielfach glaubt man ein gutes Durchschnittshandstück geschlagen zu haben und führt alle Untersuchungen an ihm aus. Dies kann aber unbeabsichtigt zur Handstückspetrographie führen. Das beste Mittel dem zu begegnen ist die systematische Probenahme aus einem kleinen Haufwerk kleingeschlagener, möglichst

†) A. W. Rogers and A. L. du Toit, The Sutherland Volcanic Pipes and their relationship to other vents in South Africa, Trans. S.A. Phil. Soc. Vol. XV, 1904.

frischer Gesteinsstücke und die Entnahme einer Serie von Proben über einen weiten Durchschnittsquerschnitt. Diese Methode habe ich bisher mit besten Resultaten angewendet.

b) Was nun die Analysen betrifft, so ist es eine bekannte Tatsache, dass besonders bei den älteren die Bestimmungen 1) des K_2O und Na_2O, 2) ebenso die des Al_2O_3, MgO und CaO und 3) die des Fe_2O_3 und FeO, sowie die Bestimmung wenig häufig erscheinender Elemente nicht mit der gewünschten Genauigkeit ausgeführt worden sind.

Wenn Analysen von Gesteinen zur genauen Feststellung ihres Chemismus überhaupt gefertigt werden sollen, so müssen sie bei allen Elementen, auch bei den in geringer Menge vorhandenen absolut zuverlässige Daten bringen. Na und K sollten stets nach den verlässlichsten Methoden doppelt bestimmt werden. Für Fe und Al und Mg und Ca sind doppelte Trennungen notwendig, eventuell auch doppelte Bestimmungen. Auf weitere Einzelheiten will ich hier nicht näher eingehen.

V. *Wert der diagrammatischen Gesteinsprojektionen.*

Im Vorstehenden habe ich versucht, die von Niggli empfohlene projektive Darstellungsweise des Chemismus zur Klärung von petrologischen Problemen südafrikanischer Gesteine, insbesondere der Differentiation und der provinziellen Verhältnisse heranzuziehen. In den meisten Fällen erweist sie sich als eine durchaus brauchbare und verlässliche Methode zur Vergleichung von Gesteinen und Gesteinsverbänden und sie lässt uns dabei leichter und übersichlicher die übereinstimmenden und trennenden Merkmale und auch die ursächlichen Zusammenhänge herausfinden, als es bei anderen Methoden möglich ist.

Die vergleichende Darstellung des Gesteinschemismus und die kritische Auswertung der hierbei gewonnenen Daten lassen uns somit verwandtschaftliche Beziehungen und auch feine Unterschiede und Besonderheiten erkennen, die uns in den Analysenresultaten, in den Molekularproportionen und ebenso auch in dem Mineralbestand, sei er mikroskopisch oder rechnerisch ermittelt, nicht so klar vor Augen treten. Sie wird dadurch ein unentbehrliches Hilfsmittel der Petrologen zur Entzifferung von Differentiationsproblemen und der provinziellen Zusammenhänge von Gesteinen und Gesteinsverbänden.

Nachtrag.

In den Führerbüchern des XV. Internationalen Kongresses zu den Exkursionen nach dem Vredefort Granit Dom und ins Bushveld sind eine Anzahl neuer Analysen mitgeteilt worden, die noch kurz besprochen werden sollen.

a) Bushveld-Gesteine.

Die Felsite Bu 1 und Bu 3 stehen durch ihr hohes mg abseits aller bisher erwähnten. Der Felsit Bu 2 und auch die Granophyre Bu 4 und Bu 5 gleichen durchaus den in Abschnitt I bezw. II 1 d besprochenen entsprechenden Gesteinen.

Die Anorthosite Bu 17 und Bu 18 stimmen mit den beiden Da 24 und Da 25 verhältnismässig gut überein, mit denen sie eine den Noriten verknüpfte Untergruppe bilden.

Trotz der grossen Verschiedenheit in der Zusammensetzung der Nephelingesteine Bu 20 und Bu 21 lässt das k : mg — Diagramm ihre enge Verwandtschaft und zugleich auch ihre provinzielle Sonderstellung zu den übrigen foyaitischen Magmen erkennen. Die weitauseinanderliegenden c/fm wie überhaupt die auffallend stark abweichenden Projektionswerte für das Differentiations-Diagramm weisen unbedingt auf Assimilation hin.

b) Gesteine aus dem Areal des Vredefort Granit Doms.

Ein auffallend niederes k und hohes c/fm weisen den beiden Graniten Vr. I und Vr XX eine Sonderstellung zu, die diese Gesteine von dem sogenannten "Alten Granit" als auch von den jüngeren Bushveld-Graniten unterscheidet.

Bei den 3 Alkaligraniten Vr IX X, XI haben wir ein gleich niederes k, was auf eine gewisse Verwandtschaft mit den Graniten Vr I und Vr XX hindeuten mag, die c/fm — Werte, insbesondere das niedere c und verhältnismässig hohe alk jedoch lassen auf eine extreme Differentiation schliessen.

Die 3 Enstatitgranophyre Vr V, VI, VII bilden bei auffallend gleichem Chemismus und hohem mg eine wohl charakterisierte Untergruppe, die verwandte Merkmale mit den Gabbrogesteinen erkennen lässt.

Vergleicht man die beiden Canadite Vr XII und Vr XIII mit dem Foyait Vr XIV und anderen südafrikanischen foyaitischen Gesteinen, so finden wir leidlich gute Uebereinstimmung.

Die basischen Gesteine Vr II, III, IV und Vr VIII entsprechen sich chemisch vollkommen. In den Diagrammen liegen ihre Projektionspunkte eng zusammen, und zwar stets auf der Seite des grossen gabbroiden Feldes (Diabase etc.), die den granitischen Magmen abgewendet und den foyaitischen zugewendet ist. Darin zeigt sich eine Uebereinstimmung mit den älteren Graniten Vr I und Vr XX.

Die eigenartigen "Flinty Crush Rocks" dokumentieren in den Projektionswerten noch klarer als es in den Analysen zum Ausdruck gelangt, einen übereinstimmenden Chemismus mit den Gesteinen, in denen sie aufsetzen. Dies gilt ganz besonders für Vr XVI und Vr XIX. Das Gestein Vr XVII hat bei niederem al ein auffallend hohes mg, was zu einer erneuten Untersuchung Veranlassung geben sollte. Reduziert man mg auf, 0, 53, so würden die Projektionspunkte mit den 4 gabbroiden Gesteinen in Einklang

stehen. Immerhin zeigen sich auch so schon die verwandtschaftlichen Beziehungen dieses "Flinty Crush Rocks" mit den Gabbros.

Die beiden anderen Vr XV und Vr XVIII lassen einen direkten Vergleich mit den durchsetzten Gesteinen nicht zu, da Analysen dieser Gesteine fehlen. Es besteht jedoch eine enge Beziehung zwischen Vr XVIII und dem von Daly beschriebenen feldspatisierten Quarzit Da 37, den man wohl zum Vergleich heranziehen kann, umsomehr als die von "Flinty Crush Rocks" durchsetzten Quarzite im Kontakt mit dem Granit stehen.

Erläuterungen zur Herkunft des Analysenmaterials.

Die Nummern *Rg* 4 — 62 entsprechen den Nummern auf Tabelle III in meiner Abhandlung "Verbandsverhältnisse und Chemismus der Gesteine des Bushveld Igneous Complex Transvaals und das Problem seiner Entstehung." N. Jahrbuch für Min. etc. B.Bd.LVI, Abt. A. Seite 631-664.

Nummer *Sh* I findet sich in S. J. Shand, The Igneous Complex of Leeuwfontein Trans. Geol. Soc. S.A. 1921 S.241, die Nummern *Sh* II und III sind aus S. J. Shand, The Alkaline Rocks of the Franspoort Line, Pretoria, Distr. Transvaal. Trans. Geol. Soc. S.A. 1922, Seite 95, die übrigen Nummern *Sh* IV — X aus S. J. Shand, The Geology of Pilansberg etc., Trans. Geol. Soc. S.A. 1928 entnommen worden.

Die Nummern *Ka* XII etc. entsprechen den betr. Nummern in E. Kaiser, "Die Diamantenwüste Südwestafrikas," Bd. I, 1925, die Nummern *Du T* 23 etc. den bezüglichen Nummern in A. L. du Toit, The Geology of South Africa, 1926.

Alle Nummern *Wa* I — XI entstammen P. A. Wagner, The Diamond Fields of S.A. 1914. —

Die später noch einbezogenen Analysen *Da* 1 — 38 und *Da* I — IX sind aus R. A. Daly, Bushveld Igneous Complex of the Transvaal, Bull. Geol. Soc. of America 1928 p. 703—768 entnommen worden.

Die arabischen Nummern ohne nähere Vorbezeichnung beziehen sich auf meine in diesem Band veröffentlichte Abhandlung "Differentiation der Karroo-Eruptiva im südlichen Kaokofeld, Südwestafrika."

In einem Nachtrag wurden noch eine Anzahl neuer Analysen kurz besprochen, die in den Führerbüchern zu den während der Tagung des XV. Internationalen Geologen Kongresses unternommenen Exkursionen nach dem Vredefort Granit Dom (Vr . . .) und dem Bushveld (Bu . . .) veröffentlicht worden sind.

8. RAPPORTI FRA ATTIVITÀ MAGMATICA E VICENDE TETTONICHE NELLA PROVINCIA PETROGRAFICA DI PREDAZZO (TRENTINO, ITALIA.)

PER

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Entro l'area delle Dolomiti di Fiemme e Fassa nel Trentino sono particolarmente bene manifesti i segni di una intensa attività magmatica. Questa si è svolta in due cicli orogenetici: uno prealpino, l'altro alpino.

Prodotti del *ciclo prealpino* sono i porfidi quarziferi, le porfiriti quarzifere ed altre porfiriti di varia composizione, i melafiri e le ripetute intercalazioni di tufi del Permiano, che costituiscono la "Piattaforma porfirica atesina," elemento strutturale di primo ordine in questo settore delle Alpi Orientali, occupato principalmente dal la Venezia Tridentina.

Queste rocce, bene rappresentate nel territorio eruttivo di Predazzo e Monzoni ed in Valsugana, formano il basamento di gran parte delle Dolomiti occidentali.

Le eruzioni dei porfidi, così frequenti ed estese nel Permiano delle Alpi Meridionali, ma anche nella Penisola Balcanica, nell'Europa Centrale ed altrove, sono, come è generalmente noto, le ultime manifestazioni dell'attività magmatica, che ha accompagnato *l'orogenesi ercinica*. Possiamo considerarle come equivalenti effusivi dei grandi massicci granitici del Paleozoico recente. Per la piattaforma atesina si presenta l'ipotesi di un legame genetico, più o meno stretto, con qualcuna delle masse intrusive della regione, p. es. col massiccio di Cima d'Asta. La supposizione è avvalorata dal fatto che le colate di porfido, pur essendo in Valsugana quasi a contatto con i nuclei di granito e di diorite, non vennero da questi metamorfosate.

L'attività magmatica del *ciclo alpino* nel territorio di Predazzo, si è svolta in due tempi: una prima manifestazione vulcanica ha preceduto la fase embrionale dell'orogenesi entro la geosinclinale mesozoica (Trias medio delle Dolomiti); l'altra ha accompagnato la crisi di maturità della Catena Alpina, cioè l'emersione della stessa (Terziario inferiore.)

La prima fase è stata essenzialmente effusiva. Suoi prodotti sono: le porfiriti augitico-plagioclasiche (andesiti mesozoiche), le porfiriti augitiche (porfidi augitici dei vecchi autori), i melafiri, i diabasi e le rispettive rocce piroclastiche del Ladinico.

La seconda invece fu una fase prevalentemente intrusiva. A questa appartiene quella associazione di rocce magmatiche, che noi indichiamo brevemente col nome di "Provincia petrografica di Predazzo." Si tratta cioè di monzoniti e facies differenziate, dioriti e gabbri con plagioclasiti, pirosseniti e peridotiti da un lato sieniti e graniti con apliti e lamprofiri dall'altro; ai quali tipi va aggiunto inoltre un gruppo di rocce nefeliniche, molto interessanti.

L'attività magmatica del Trias medio, allo stesso modo come quella del Permiano, sopra ricordata, non è un fenomeno particolare del territorio di Predazzo e Monzoni, ma generale della Zona Dinarica tanto nelle Alpi Meridionali quanto nella Penisola Balcanica.

Nel Trentino questa attività fu soltanto più intensa che nelle altre regioni.

Le eruzioni, basiche nelle Dolomiti, ma altrove anche acide, sono da mettersi in rapporto con fratture, che hanno colpito l'orlo meridionale della geosinclinale mesozoica per l'abbassamento della Tetide. La diffusa mineralizzazione, principalmente con formazione di giacimenti metasomatici di galena e blenda nel Trias delle Alpi Orientali, è un fenomeno endogeno che, anche per ordine di grandezza, può stare in relazione con questa ed ineguale attività magmatica, della quale esso rappresenta un prodotto di distillazione da un esteso bacino regionale.

Successivamente l'attività del substrato magmatico si è svolta entro la zona assiale della geosinclinale (associazione di pietre verdi e calcescisti dell'Unità Pennidica), per riprendere ancora verso la fine del Cretaceo nella zona esterna meridionale e continuare qui durante il Terziario.

Questo risveglio del vulcanismo entro la Zona Dinarica durante l'emersione della Catena Alpina fu ancora una volta particolarmente intenso nella Regione Veneta entro il bacino dell'Adige ed aree limitrofe. Testimoni della rinnovata attività magmatica sono il massiccio tonalitico dell'Adamello e presumibilmente altri nuclei lungo il limite alpino-dinarico, il focolaio trachitico Euganeo, le colate basaltiche dei Lessini. Le iniezioni di un magma estremamente differenziato nelle Dolomiti del Trentino, cioè i classici centri di Predazzo e Monzoni, appartengono pure alla stessa fase.

* * *

Se l'importanza e l'interesse geologico di un territorio eruttivo dovessero dipendere soltanto dalla sua estensione e dalla sua mole, a Predazzo spetterebbe un posto ben modesto. Basta tener presente che gli affioramenti delle rocce intrusive occupano qui una superficie di appena 12 Km.^{2} Il

piccolo corpo magmatico di Predazzo è un pigmeo di fronte al colosso dell'Adamello con 550 Km^2 di estensione superficiale!

La rinomanza di Predazzo non è dunque in funzione della quantità della massa, bensi della sua qualità veramente fenomenale: un intricato e variopinto groviglio, che dal lato genetico rappresenta un affascinante problema da risolvere.

La storia di questo enigma geologico è nel tempo stesso una pagina luminosa di storia della Geologia, alla quale sono legati in modo indissolubile i più bei nomi di ricercatori di quasi tutte le nazioni civili d'Europa.

L'aver condotto a termine il rilevamento di dettaglio di una nuova carta geologica di questo molto complicato territorio m'induce ad esprimere sulla più che secolare questione un pensiero fondato sopra osservazioni dirette sia sul terreno che al microscopio.

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Dalle vicinanze del Passo Feudo, nei dintorni di Predazzo, ai piedi della Catena di Costabella .cioè al gruppo dei Monzoni, sono allineati in modo discontinuo lungo un tratto di circa 18 Km. parecchi piccoli nuclei di rocce intrusive, particolarmente numerosi presso Predazzo. Nel settore montuoso dove affiorano queste rocce si possono esaminare profili di quasi 2000 m. essendo Predazzo a 1000 m. e le cime della Costabella a circa 3000 m.

Si tratta di un territorio colpito da numerose fratture. Tutta la serie, dal Paleozoico (Permiano) al Trias medio, compresi pure i banchi di lava e di tufi del Ladinico, è fortemente dislocata. Sono risparmiate invece le masse intrusive, le quali presentano soltanto qua e là piccoli disturbi di assestamento.

L'ordine di grandezza della deformazione tettonica è evidente in particolar modo nei fortissimi dislivelli entro la piattaforma porfirica permiana, sbloccata, la quale in Val d'Adige, presso presso Ora a Sud di Bolzano, sparisce sotto le alluvioni a circa 220 m., mentre nei dintorni di Predazzo culmina a circa 2800 m., con salti anche di 1500 m. lungo lo stesso piano di frattura.

Siamo indubbiamente in presenza di dislocazioni di tipo alpino. Queste fratture si inseriscono infatti tanto per entità che per andamento nel sistema di linee di struttura del Terziario delle aree attigue.

Il raccordo è stabilito principalmente dalla "linea di Trodena," una frattura che dai dintorni di Trento (Monte Corona) attraversa con un taglio secco il territorio alla sinistra della Valle dell'Adige per poco meno di 50 Km. fino ai piedi delle Dolomiti di Fiemme (Làtemar) ed è caratterizzata da sprofondamenti anche di circa 2000 m: contatti verticali con poderosa triturazione fra i porfidi permiani della piattaforma atesina e la serie mesozoica conservata qui fino alla Dolomia Principale del Trias alla base del tratto Paganella-Mendola, dove sono d'altra parte implicati anche il Cretaceo e l'Eocene.

Fra il Passo di S. Lugano (dintorni di Cavalese) ed il Passo Feudo (dintorni di Predazzo) al posto della linea di Trodena subentrano numerose fratture. La più importante di queste è la "linea di Stava," che entra nel territorio di Predazzo. Qui le dislocazioni hanno seguito più direzioni, complicando la struttura di dettaglio con sprofondamenti ad imbuto; persiste tuttavia una direzione di più intensa dislocazione, la quale continua fino nel territorio dei Monzoni. Più oltre, cioè nel settore Costabella-Marmolada, cambia stile tettonico: al posto delle grandi fratture subentrano pieghe, rovesciamenti e piccoli ricoprimenti. Si sente che nell'infrastruttura viene a mancare l'elemento rigido: la piattaforma porfirica.

Dopo la scoperta, da me fatta, di piccoli nuclei di monzonite nel territorio fra Predazzo e Monzoni l'allineamento delle singole masse intrusive entro la zona più intensamente dislocata è di una evidenza, che non ha bisogno di molte spiegazioni.

E ciò tanto più se si tiene presente che nella stessa direzione l'iniezione filoniana è particolarmente abbondante e varia e che qui pure sono manifesti metamorfismi di contatto, anche nei tratti dove non affiorano le masse intrusive.

Il magma salendo lungo i profondi piani di frattura ha preso corpo, a mio modo di vedere, in forma in un gigantesco filone, o quasi di una lama, che penetra verticalmente nella serie molto dislocata delle Dolomiti di Fiemme e Fassa per una lunghezza, come s'è accennato, di circa 18 Km. e per una potenza variabile fino ad un massimo di quasi 2000 m.

Le piccole masse direttamente accessibili alla nostra osservazione non sono altro che grosse apofisi, più o meno differenziate, che si staccano dal sottostante grandioso filone, del quale a Predazzo ed ai Monzoni affiorano le estremità.

A prima vista questa interpretazione delle masse intrusive della nostra provincia petrografica, così riunite in un corpo geologico inserito nella struttura regionale, pare urti contro una difficoltà. Nelle immediate vicinanze di Predazzo le masse cioè non sono allineate, ma disposte ad arco attorno al Monte Mulàt.

L'arco delle intrusioni (Canzòcoli, Malgola, Mulàt S W - S E) si estende però per meno di 5 Km., mentre l'allineamento principale, che non passa per il paese di Predazzo ma per Val Gardonè, Mezzavalle, la Miniera Bedovìna e la Val della Vièzzena ha una estensione quasi quadrupla.

Dunque a Predazzo, loco, ci troviamo davanti ad una complicazione locale, che potrebbe fuorviare chi non tiene presente la geologia di tutta la regione. Nel quadro d'insieme però questi particolari acquistano il significato di un dettaglio, per quanto interessante ed importante si voglia.

Un nucleo di porfirite triassica (Mulàt), che rappresenta la parte profonda di un antico centro eruttivo demolito, ha determinato con la sua resistenza passiva alla deformazione tettonica di questo settore (sinclinale del

Travignolo) un sistema di fratture circolari, attraverso alle quali si è insinuata una parte del magma riattivato dalle dislocazioni regionali.

Queste sono state particolarmente intense qui a tergo del grande punto fisso di arresto, constituito dal massiccio di Cima d'Asta, nucleo granitico profondamente radicato nella grande anticlinale scistoso-cristallina della Valsugana, alla base delle Dolomiti di Fiemme.

Ai Monzoni, invece, dove non è stato colpito un centro eruttivo triassico - quelli di Buffaure nell'alta Val di Fassa restano fuori dalla grande linea di frattura - rapporti di giacitura sono di una evidenza esemplare, veramente scolastica. Il magma, non ostacolato, potê ascendere unito in massa seguendo il piano rettilineo di frattura e costituire quel grandioso dicco lungo circa 5 Km. che, limitato a Sud dalla anticlinale di Bocche ed a Nord da quella di Contrìn-Lagusél, sporge attraverso la serie del Permiano e del Trias inf. e medio dei gruppi dolomitici della Vallaccia e della Costabella, serie profondamente dislocata ed intensamente metamorfosata ai magnifici contatti, divenuti classici nella letteratura geo-mineralogica.

Il metamorfismo ha fissato nei sedimenti anche piccole pieghe e fratture di dettaglio, riflesso di ben maggiori dislocazioni. Queste hanno evidentemente preceduto ed accompagnato l'intrusione per poi estinguersi rapidamente. Come ho potuto vederlo nei massicci terziari di Bregaglia e del l'Adamello, così anche a Predazzo, ma in special ai Monzoni, si hanno però anche zone di schiacciamento più recenti della consolidazione della massa magmatica, piazzatasi là dove ora possiamo osservarla, in quanto è stata scoperta per demolizione del mantello sedimentare a partire dal Miocene.

Alla provincia petrografica di Predazzo appartiene adunque un'associazione di rocce intrusive e filoniane differenziate, contemporanee, cioè prodotte da una rinnovata attività magmatica durante il Terziario inferiore in conseguenza delle intense fratture, le quali, per un grandioso sforzo di torsione dell'arco alpino, hanno colpito allora in particolar modo l'area centrale delle Dolomiti di Fiemme e Fassa, aventi nella potente piattaforma porfirica un substrato rigido.

La dibattuta questione dell'età del fenomeno intrusivo ritengo vada risolta così.

* * *

Richthofen, Mojsisovics, Reyer, F. Suess, Broegger, Doelter ed i suoi numerosi allievi, Hoernes e molti altri studiosi erano dell'opinione che a Predazzo ed ai Monzoni si avesse avuto una manifestazione vulcanica unica, tutta di seguito a partire dal Trias medio.

Salomon, la signora Ogilvie-Gordon, H. Philipp, J. Romberg, W. Penck hanno supposto od affermato, portando in parte anche prove, che il fenomeno si é svolto in tempi bene distinti. Una dimostrazione geologica

convincente non si era però imposta, per cui i pareri sono rimasti piuttosto discordi fino negli ultimi anni.

L. Kober e R. Staub per considerazioni orogenetiche d'indole generale hanno accettato le intrusioni di Predazzo come terziarie, senza aver però dedicato ricerche particolari al problema.

Di questa opinione, ma per considerazioni petrologiche, era anche, L. Brugnatelli, il quale però, pur conoscendo il territorio dei Monzoni per esperienza propria, non ci lasciò scritto nulla al riguardo, limitandosi a far eseguire solo qualche studio mineralogico di dettaglio da alcuni suoi allievi.

Invece tanto in occasione del 9° Congresso Geologico Internazionale (Vienna 1903), quanto nel 33° Congresso Nazionale, Italiano, (Padova 1920), le escursioni attraverso il territorio eruttivo di Predazzo e Monzoni furono guidate per mostrare un esempio tipico di "cicatrice vulcanica," cioè di un apparato completo, più o meno profondamente intaccato, una specie di vulcano fossile triassico.

Questa interpretazione, sostenuta da studiosi di grande autorità, venne seguita dapprima anche da me; in un secondo tempo però, esteso lo studio geologico a tutta la regione, mi sono persuaso che rispondeva meglio ai fatti osservati una distinzione netta dell'attività magmatica in due fasi: l'una effusiva triassica, l'altra intrusiva terziaria, come ho accennato sopra e come verrà esposto in una prossima memoria illustrativa.

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I rapporti fra deformazioni tettoniche ed attività magmatica pare non si arrestino però al solo fenomeno geologico della dipendenza del vulcanismo dalle dislocazioni.

Tenuta presente la costituzione della infrastruttura del territorio eruttivo di Predazzo e Monzoni, pare che anche il fenomeno petrologico della differenziazione magmatica dipenda in qualche modo dalla tettonica.

Come s'è ricordato, abbiamo a che fare qui con la sovrapposizione di tre, e presumibilmente ancor più, manifestazioni vulcaniche molto intense dal Paleozoico al Terziario. E' possibile che, anche a distanza di tempo, le precedenti abbiano influito in qualche modo sulle seguenti?

Il problema non è semplice, essendo profonda la sede del fenomeno, che sfugge alla nostra diretta osservazione. Si tratta cioè di una questione, diremo così, fisiologica di assimilazione e rigenerazione di masse magmatiche antiche. Dunque un interessante problema di geochimica, d'indole generale.

Ma vediamo innanzi tutto le constatazioni di fatto.

Le rocce magmatiche della provincia petrografica di Predazzo, considerate come parti di un corpo geologico, tenuta presente la loro distribuzione topografica ed i loro rapporti reciproci di giacitura nonchè la loro composizione chimica e mineralogica, con le rispettive variazioni di struttura, sono l'espressione manifesta di una inomogeneità laterale entro il gigantesco filone.

A grandi linee infatti, se incominciamo dall'estremità N E dei Monzoni e procediamo verso Predazzo, si constata una crescente acidità delle singole masse che dai tipi gabbrici di Allochèt passano alle dioriti della Ricoletta, alle monzoniti del Malinverno e di tutto il tratto intermedio (Rezìla, Vièzzena), alle monzoniti, sieniti ed al granito dei dintorni di Predazzo.

Per quanto in realtà il passaggio non sia così schematico come lo indicano i nomi delle località citate, cosa che apparirà più precisamente in dettaglio sulla nuova carta geologica, sta il fatto che ai Monzoni prevalgono tipi poveri di silice, mentre a Predazzo sono bene rappresentati anche quelli molto silicei. A questa diversità sostanziale, che non era passata inosservata ai vecchi ricercatori, bisogna aggiungerne un'altra non meno importante.

Mentre a Predazzo i singoli tipi costituiscono di preferenza corpi relativamente autonomi, abbastanza bene definiti, pervenuti cioè al loro posto per iniezioni successive, ai Monzoni invece il grande dicco presenta variazioni piuttosto rapide da un tipo all'altro in maniera che in un punto della massa di composizione monzonitica si hanno estese plaghe di concentrazioni gabbriche, in un altro della massa gabbrodioritica si notano concentrazioni monzonitiche. Questa tendenza ad una instabilità petrografica, così caratteristica delle rocce monzonitiche, è manifesta anche a Predazzo, ma non in misura tanto grande come ai Monzoni. Molte questioni controverse di dettaglio sull'età relativa delle singole rocce vanno risolte in questo senso.

Non trova poi riscontro nei rapporti di giacitura, realmente constatabili per le rocce intrusive, il presunto ordine di differenziazione ideale, cioè in una facies periferica basica ed in un nucleo sempre più acido, come ha creduto di vedere qui anche qualche autorevole ricercatore, ad esempio Broegger. La spiegazione di questi fatti è da ricercarsi forse nella composizione chimica del magma monzonitico, che—come è noto—si avvicina più di ogni altra alla media calcolata per tutte le rocce eruttive e vorebbe rappresentare quindi un ipotetico magma tellurico, generale, facilmente scindibile.

Ma io sono del parere che le vicende geologiche, assodate nel nostro settore, abbiano pure la loro parte.

Si constata cioè che la differenziazione magmatica, incominciata prima dell'intrusione, è continuata anche durante la stessa. Così dove la dislocazione ha aperto una unica via all'ascesa del magma, questo è stato iniettato in massa cospicua e quindi per raffreddamento ha avuto luogo la segregazione dei tipi in sito (Monzoni—dicco complesso.) Dove invece la deformazione tettonica è avvenuta per sprofondamenti successivi, in conseguenza di particolari condizioni strutturali, locali, è stata favorita l'iniezione di singole porzioni di magma relativamente differenziate (Predazzo—serie di grosse apofisi a composizione diversa: monzonite, sienite, granito).

Così si potrebbe credere di essere arrivati ad una soluzione relativamente semplice del problema della differenziazione magmatica nella provincia petrografica di Predazzo. Senonchè lo svolgimento del fenomeno deve essere stato di gran lunga più complesso. Lo attesta la presenza di un ricco seguito filoniano, che comprende da un lato varie specie di apliti e pegmatiti e dall'altro lamprofiri, alcuni anche rarissimi riferibili in parte alla serie camptonitica. E la complicazione è ancor più accresciuta dalla presenza di rocce nefeliniche, rispettivamente ad anfiboli e pirosseni alcalini.

Ora l'esperienza geologica nelle più lontane regioni della Terra ci mostra che le rocce nefeliniche, piuttosto rare, sono il prodotto di fattori locali, del tutto particolari, cioè di accidenti che modificano, che turbano, lo svolgimento normale della differenziazione magmatica.

A queste difficoltà si aggiunge inoltre quella di spiegare il chimismo della differenziazione in un magma monzonitico, dal quale si sarebbe formato anche il granito tormalinifero, che dimostra di avere ben poca "consanguineità" con le monzoniti, pur essendosi piazzato poco dopo di queste.

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Si presenta adunque la questione se proprio tutte le rocce della provincia petrografica di Predazzo provengono da un unico magma.

Ed in caso affermativo se questo magma è lo stesso che ha fornito il materiale alle colate porfiritiche e melafiriche del Ladinico. Oppure se l'attività magmatica del Terziario a Predazzo è legata ad un apporto di nuove masse, o sostanze, elaborate altrove in profondità e successivamente spostate per oscuri movimenti subcrustali in consequenza del grande turbamento orogenetico.

Elementi positivi sui quali potremmo forse basare una interpretazione che tenga conto tanto delle condizioni locali, che della diversità fra la nostra provincia e gli altri centri eruttivi contemporanei della regione sono, a mio modo di vedere, in primo luogo le analogie chimiche, cioè sostanziali, fra i prodotti dell'attività magmatica recente, della quale stiamo occupandoci, e quelli di manifestazioni precedenti entro lo stesso settore.

Quando si riteneva che il vulcanismo di Predazzo fosse tutto triassico, si credeva di vedere nella monzonite la facies intrusiva della porfirite; nel gabbro quella del melafiro. Restava però sempre lo scoglio del granito. Per questo mancava l'equivalente.

La possibilitè di un legame sostanziale fra le rocce effusive triassiche e le intrusive terziarie, di composizione chimica pressochè eguale, non è da escludersi però neppure ora anche stando alle moderne vedute sul magmatismo.

Le enormi pressioni determinate dai crolli catastrofici di zolle, che la conoscenza della struttura geologica regionale ci autorizza ad ammettere nel Terziario, devono aver reso plastici, analogamente a quanto risulta da

esperienze di laboratorio, i materiali ammassati nell'infrastruttura durante l'attività magmatica del Trias. A riattivare queste masse consolidate possono aver contribuíto il calore ed i prodotti volatili sprigionatisi da un più profondo, esteso bacino magmatico regionale sul quale è venuta a trovarsi quella parte della geosinclinale che nell'orogenesi doveva dar luogo alla Zona Dinarica.

Così si può forse spiegare la alcalinità un po'maggiore nella monzoniti rispetto alle porfiriti e la mineralizzazione sporadica entro le prime. Naturalmente secondo questa interpretazione le monzoniti non sono state mai in precedenza porfiriti, ma le une e le altre sarebbero rami cresciuti dallo stesso tronco in tempi diversi ed in condizioni d'ambiente diverse, cioè prodotti essenzialmente dello stesso magma.

Per dare un'idea dell'ordine di grandezza delle enormi pressioni che la sorte tettonica aveva riservato nel Terziario al nostro settore bisogna tener presenti i milioni di atmosfere, che ha dovuto sopportare la infrastruttura per la caduta delle singole zolle. Ad esempio il piccolo settore del Monte Agnello, fra la linea di Stava, il Passo Feudo e Predazzo, che aveva allora un volume di circa 100 $Km.^3$ ed un peso di circa 250 miliardi di tonnellare, si è sprofondato di non meno di 1000 m. E questo non è che uno dei tanti frammenti dislocati prima dell'intrusione monzonistica. In simili condizioni è il caso di chiedersi se una riattivazione magmatica, cioè un risveglio del vulcanismo non doveva agire anche sulle masse eruttive preesistenti.

Particolarmente interessante al riguardo è la questione dell'origine del granito tormalinifero di Predazzo, per il quale, come si è accennato, si cercherebbe invano un equivalente nella serie effusiva triassica. Esiste invece una somiglianza fra la composizione del granito roseo terziario e quella del porfido quarzifero rosso permiano della regione.

L'idea, espressa anche da F. v. WOLFF, che il granito di Predazzo possa essere un antico porfido rigenerato, per quanto ardita, non pare assurda e ciò per considerazioni sopra dati positivi chimici, petrografici e geologici.

Le analisi chimiche delle due rocce ci mostrano solo piccole differenze. Il granito di Predazzo, come già parecchi visitatori l'hanno osservato, è spesso molto poco granitico, pur essendosi consolidato a notevole profondità; inoltre esso abbonda di inclusioni vetrose microscopiche. La forza ascensionale di questa roccia poi pare sia stata piuttosto piccola, infatti la massa intrusiva non ha raggiunto livelli stratigrafici così elevati come la monzonite iniettata dallo stesso granito. Di particolare interesse è poi la presenza degli inclusi nei tufi del Ladinico.

Le rocce piroclastiche del Trias medio delle Dolomiti di Fiemme e Fassa sono o tufi basali, per lo più verdi, prodotti dalle esplosioni, che hanno preceduto le prime eruzioni, oppure tufi da bruni a neri, intercalati fra le successive colate; in ambedue i casi originariamente in giacitura

orizzontale; altri tufi da ultimo attraversano verticalmente la serie sedimentare e formano il riempimento di diatremi.

Nei tufi basali, ricchi di frammenti calcarei, abbondano localmente anche gli inclusi di porfido quarzifero permiano insieme con quelli di scisti cristallini dell'infrastruttura. La loro presenza è un indizio della violenza delle esplosioni, che hanno preceduto le estrusioni laviche del Ladinico.

In qualche affioramento di tufi nerastri o grigi (Viezzena, Mezzavalle) si trovano poi anche frammenti di rocce granitiche, segnalati per la prima volta da J. Romberg. Non solo io confermo questa importante scoperta, ma sono in grado di indicare qualche altro affioramento (Sorte presso Moena), dove in un piccolo cratere d'esplosione sono frequenti grossi inclusi di una roccia granulare a feldspati rossi, piuttosto granitica che porfirica.

Non vi è dubbio quindi che al tempo dell'attività magmatica del Trias medio nell'infrastruttura di Predazzo esistesse già un granito, mentre nulla ci autorizza ad ammettere che allora vi fossero le monzoniti, le dioriti e le altre rocce intrusive.

D'altra parte il granito terziario di Predazzo è più recente della monzonite.

A priori si potrebbe pensare che gli inclusi granitici provengano da un antico massiccio iniettato negli scisti e coperto dai porfidi, forse in continuazione di quello di Cima d'Asta secondo una vecchia interpretazione di E. Suess.

Fra gli inclusi scistosi non sono stati però trovati frammenti di filladi metamorfosate per contatto, per cui questa attribuzione pare poco probabile.

Gli inclusi granitici potrebbero rappresentare la facies intrusiva di qualche colata di porfido permiano; cioè nell'infrastruttura di Predazzo esisterebbe una delle fessure eruttive degli antichi porfidi. Questa supposizione è verosimile anche in considerazione che nel settore dei Monzoni si constatano parecchie eruzioni di porfidi e porfiriti del Permiano.

C'è inoltre una terza possibilità: gli inclusi granitici dei tufi ladinici sarebbero frammenti staccati da qualche zolla di porfido quarzifero caduta nel bacino magmatico triassico, e poi ricristallizzati. Questa interpretazione pare la più adatta per gli inclusi del diatrema di Sorte.

La trasformazione del porfido in granito per azione di un magma più recente è un fenomeno possibile. Per analogia ricordo che proprio ai Monzoni (Pesmeda), un tufo di porfirite quarzifera, sicuramente permiana, è divenuto così cristallino al contatto con la monzonite, che Doelter l'ha segnato erroneamente come monzonite, mentre il passaggio graduale dalla roccia originaria alla sua facies metamorfa è evidente.

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Valutati i fatti accertati, ponderati i casi possibili, si può pensare che singole zolle della piattaforma porfirica, sbloccata, abbiano subito una rigenerazione per l'attività magmatica del ciclo alpino.

In questo modo nella Provincia petrografica di Predazzo si avrebbe a che fare con un magma misto cioè poligenico. Da ciò la impossibilità di attribuire la serie di Predazzo alla famiglia pacifica o alla famiglia atlantica nel senso di Becke, Prior ecc. Così si giustifica il tentativo di Stark di creare una famiglia intermedia, basata appunto sulla serie di Predazzo, considerata tipica.

Del resto anche con la recente, più precisa, classificazione dei magmi secondo Niggli le masse intrusive di Predazzo non rivelano una tendenza di differenziazione nè di una provincia pacifica, nè atlantica, nè mediterranea, ma mista.

La causa andrebbe ricercata appunto nelle vicende tettoniche per le quali ha avuto luogo una confusione di magmi di età diverse in un crogiuolo recente, con parziali palingenesi.

E' singolare ad ogni modo il fatto che masse intrusive contemporanee della stessa regione, come l'Adamello e Predazzo, presentino differenze così sorprendenti. Bisogna ammettere che condizioni diverse, ma principalmente una diversa costituzione dell'infrastruttura abbiano avuto la loro parte nel fenomeno della differenziazione magmatica.

Tra l'altro anche la questione dell'origine delle rocce nefeliniche di Predazzo, pare connessa con qualche causa perturbatrice locale. Non sembra però applicabile al caso nostro l'interpretazione, per quanto plausibile, ammessa (Daly, Shand ed altri) per parecchie province petrografiche, secondo la quale cioè queste rocce a feldispatoidi si sono formate per una reazione fra i carbonati del mantello e la silice del magma con arricchimento locale di alcali.

Non già che siano da escludersi fenomeni di assimilazione nella provincia di Predazzo, questi anzi sono stati presi in considerazione, specialmente da Doelter, per spiegare la maggiore basicità dei Monzoni; sta il fatto però che alla presenza di zolle calcaree entro l'ammasso intrusivo non fanno riscontro affioramenti di rocce nefeliniche.

Le rocce, alterettanto belle quanto rare, comprese fra le sieniti alcaline e le teraliti, associate anche a filoni differenziati di difficile sistemazione, che oscillano fra le beerbachiti, le kersantiti e le bostoniti, raccolte da me presso i marmi del Malinverno (Monzoni) rappresentano sfumature petrografiche senza dubbio di alto interesse genetico, tuttavia pare non dicano ancora abbastanza sopra una eventuale digestione di zolle calcaree con formazione di rocce e feldspatoidi. A meno che le rocce nefeliniche non si trovino in profondità: cosa poco probabile però, perchè entro l'area dove affiorano i marmi, avvolti dalla monzonite, i filoni sienitici nefelinici sono molto rari. Questi invece, insieme con altri tipi affini, si presentano presso Predazzo (Val Cogoletti), specialmente a breve distanza dal granito, senza però attraversarlo, presumibilmente per la incompatibilità fra il quarzo e la nefelina. Volendo attribuire ciò non ostante l'origine delle rocce nefe-

liniche ad una reazione qui avvenuta fra calcare e magma bisognerebbe ammettere una completa demolizione del mantello sedimentare per spiegare l'assenza dei marmi in prossimità di quelle. Ma ciò diventa un giuoco di possibilità alquanto problematico.

Un altro fatto invece, molto importante, messo meglio in evidenza dal nuovo rilevamento geologico, esteso a tutta la regione, e cioè anche al territorio poco noto fra i Monzoni e Predazzo, è la associazione di lamprofiri della serie camptonitica e le rocce filoniane tinguaitiche, anche a notevole distanza da affioramenti di masse intrusive monzonitiche, sienitiche o granitiche.

Questi filoni, più frequenti lungo piani di frattura, attraversano tutte le altre rocce rivelando ad un tempo una relativa autonomia rispetto a queste; compreso pure il granito, del quale perciò, a rigore, i filoni non possono essere considerati senz'altro come complementari.

Pare quindi naturale attribuire i lamprofiri, ed anche i filoni di porfido sienitico-nefelinico e quelli tinguaitici, piuttosto a residui magmatici relativamente diffusi, cioè a piccoli focolai profondi, nei quali si sono concentrati non solo i costituenti femici, ma anche quelli alcalini. Non si può escludere che come centri di attrazione abbiano agito ancora le zolle dell'antico porfido quarzifero dell'infrastruttura, immerse nel bacino magmatico e probabilmente in parte anche rigenerate in forma di granito.

Ancora un fatto di indiscutibile valore si lascia spiegare con l'attribuzione dei filoni lamprofirici alcalini a residui magmatici profondi. Alludo alla mancanza, o relativa scarsezza, di camptoniti, monchiquiti e rizzoniti in quella parte della massa intrusiva nella quale la differenziazione è avvenuta durante l'iniezione. Entro l'area N E dei Monzoni, dove il grande dicco rivela la sua complessità con le frequenti segregazioni basiche ed ultrabasiche, alle quali si è accennato, invece dei lamprofiri, residui filoniani, si hanno le pirosseniti dai limiti talora incerti, più propri di una concentrazione contemporanea che non di una iniezione successiva. Pare cioè che lamprofiri e pirosseniti si escludano a vicenda; e questo fatto starebbe in buon accordo anche con un meccanismo ideale di differenziazione.

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E' opinione generalmente accreditata che la differenziazione magmatica dipenda in primo luogo dalle condizioni chimico-fisiche nelle quali è venuto a trovarsi un magma attivato da cause tettoniche. Nel caso di Predazzo la straordinaria varietà dei tipi entro un corpo così piccolo, per cui questa classica provincia petrografica desta tanto interesse, pare sia da attribuirsi però in particolar modo alle intense dislocazioni per frattura, che hanno colpito antichi centri eruttivi riaprendo la via ad un magma elaborato durante il ciclo alpino.

La diversa distribuzione di alcuni tipi ed i rapporti fra loro dipendono evidentemente dal meccanismo dell'intrusione, che è stato vario da luogo a luogo secondo le vicende tettoniche dei singoli settori.

E' verosimile però che qualche tipo rappresenti un fenomeno di palingenesi. In questo modo si può spiegare il carattere misto della provincia petrografica di Predazzo, che non si adatta a nessuno schema di differenziazione finora ideato.

Padova, giugno 1929.

NOTA.

La ricchissima bibliografia sopra Predazzo e Monzoni è stata da me in gran parte passata in rassegna nel primo lavoro qui sotto citato.

Uno sguardo sintetico ben fatto, ma molto breve, sul problema di Predazzo è inserito in F. v. WOLFF *Der Vulkanismus*. I Vol. pag 323.=Stuttgart (Enke) 1914.

Al riguardo particolarmente interessante è poi lo studio di M. STARK sulle *Petrographische Provinzen* (Fortschritte d. Min. Krist. u. Petrogr. IV Jena 1914).

Nel seguente elenco riporto solo le principali pubblicazioni, ultimamente uscite, in alcune delle quali si tratta, anche se indirettamente, della geologia regionale che interessa il vulcanismo di Predazzo.

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„ *Nuovi rinvenimenti di materiali piroclastici nei dintorni di Moena e loro importanza per la interpretazione tettonica della regione.*
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„ *La linea della Vallarsa* (*Brantental*)—Nuovo contributo alla conoscenza della tettonica della piattaforma porfirica atesina.
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Ibid. Vol. XIX. Padova 1928.

„ *I lamprofiri della Provincia Petrografica di Predazzo* (con microfotografie, analisi e diagrammi).
Annali R. Scuola d'Ingegneria. Vol. IV. Padova 1928.

„ *Escursioni geologiche attraverso le Dolomiti di Fiemme* (con schizzi e profili).
Ibid. Vol. IV—Padova 1928.

„ *Carta geologica delle Tre Venezie* 1:100,000 "foglio Marmolada" "foglio Trento" p.p. in corso di stampa (1929); "foglio Feltre" p.p. "foglio Bolzano" p.p. di prossima pubblicazione per l'Ufficio Idrografico del R. Magistrato alle Acque—Venezia, Sezione geologica—Padova, Università.

„ *La carta geologica del territorio eruttivo di Predazzo e Monzoni* Scala 1:25,000, di prossima pubblicazione (1929) comprende le seguenti tavolette: S. Nicolò d'Ega, Moena, Passo di Valles (foglio Marmolada 11° della carta l'Italia); Cavalese, Predazzo, Paneveggio (foglio Feltre 22° della carta d'Italia), alle quali si rimanda per le località ricordate nella presente nota riassuntiva.

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ABSTRACT.

Relation between magmatic activity and tectonical deformations in the petrographical province of Predazzo (Trentino, Italy).

In Predazzo and at Monzoni occur the extreme parts (12 Km² surface) of a little magmatic body injected as a dyke of great style for an extent of 18 Km. along a deeply disturbed zone of tertiary age.

The triassic effusiva of the Dolomites (augite-plagioclase-porphyrites, augite andesite melaphyres, diabases and tuffs) are here very much dislocated, sinking at most 1500 m. On the contrary the intrusiva (monzonites with associated facies, syenites, granite, nepheline—bearing rocks and lamprophyres) are not dislocated but only little disturbed.

There is no great difference between the composition of the tertiary monzonites and that of the triassic porphyrites, being both originated from the same magmatic basin.

To the petrographical province of Predazzo, sensu stricto, belongs an association of intrusiva and dyke rocks of tertiary age. The magmatic differentiation began here before the intrusion and continued during it. We recognize in the great body of Predazzo-Monzoni a lateral inhomogeneity from one to the other end (Monzoni N E. mafic; Predazzo S W: persilicic or alcaline).

The preexistence of rocks of a prealpine (hercynic) magmatic cycle, particularly the Permian quartzporphyries, may have influenced the process of differentiation of the alpine cycle. The old "Piattaforma porfirica atesina" (porphyries of Bolzano), broke at first during the eruptions of Middle Trias (Ladinic tuffs of Predazzo with inclusions of quartzporphyries also granitic, but never monzonitic), was newly and more intensively dislocated in the tertiary age in that central area of the sector, whose arch lies in the giudicarian line and in the alpin-dinaric limit from the Val di Sole to Merano, Mules, till Val Pusteria.

Great masses of Permian porphyry, sunk in the magmatic basin, became probably regenerated (palingenesis) as tertiary granite of Predazzo (composition nearly equal).

These melted and recrystallized masses (glass inclusions in the granite of Predazzo) attracted the volatile constituents of the magma (mineralisers and alkali). The alkali, absorbed only in little quantity in the granite, concentrated in the residual part of the magma in the neighbourhood of the granitic mass (origin especially of nepheline-bearing rocks, essexites and lamprophyres of the camptonitic series). The mineralisers precipitated in the fissures of the granite (association of pneumatolytic minerals tourmaline, fluorite, apatite, chlorite, pyrite, calchopyrite, arsenopyrite scheelite in a series of nearly parallel lenticular geodes in the quarry by Mezzavalle) The same minerals are also associated in the fissures of the overlying older andesite (mine Bedovina).

In the petrographical province of Predazzo we can distinguish the following groups:

(1) the monzonite with associated facies from the quartzmonzonite (Predazzo) to the olivinemonzonite (Monzoni), with the syeniticmonzonites, the diorites, theralites and gabbros, with pyroxenites, plagioclasites and wehrlites; with its aplites and lamprophyres.

(2) The alkalisyenite with associated facies, with its aplites and porphyry, with the gauteite and the bostonite.

(3) the granite with its pegmatite and the pneumatolytic mineral-association.

(4) the nepheline-rocks with the nepheline-syeniteporphyry, the tinguaites, the essexites and the lamprophyres of the camptonitic series. .

The nepheline-rocks of Predazzo seem to be produced from the monzonitic magma in consequence of a special, local (tectonical) factor, i.e. as reaction with Permian quartzporphyry blocks.

So this very complicated petrographical province, which had a tendency to pacific differentiation, but more or less mediterranean, ended in a typical atlantic one.

SECTION II.

PRE-PLEISTOCENE GLACIAL PERIODS.

9. DERIVA DEI CONTINENTI E PERIODI GLACIALI

PER

MICHELE GORTANI.
(Bologna.)

Si può affermare che mai come oggi i problemi fondamentali della storia della Terra sono stati appassionatamente discussi, che mai come oggi la loro soluzione è stata cercata per le vie più divergenti, che mai più di oggi al critico obiettivo sono apparse incerte le basi stesse dell'umano sapere. Ma non per questo lo scetticismo deve impadronirsi di noi. Anche per la geologia, come per le altre scienze, sarà benefica la crisi attuale; e, mentre ci porterà ad una miglior valutazione delle nostre forze e delle nostre conoscenze, sboccherà in costruzioni teoriche meglio poggiate sui fatti e progredite rispetto a quelle anteriori.

Le varie teorie degli spostamenti continentali, su cui Wegener è riuscito (e questo è il principale suo merito) a far convergere il pensiero e le discussioni degli studiosi, hanno gran parte in cotesto lavoro di revisione e di elaborazione. Esse infatti hanno spostato di colpo i cardini della paleogeografia, così nelle ricostruzioni delle aree emerse e dei mari, come dei climi e degli ambienti biologici, e così nelle applicazioni particolari come nell'interpretazione delle cause generali da cui dipende la vita del globo e dei suoi abitanti. Altrove (1) ho avuto occasione di discutere tali teorie nei riguardi dell'orogenesi ed epeirogenesi; nella presente nota mi limiterò ad esaminare i rapporti di esse col problema delle glaciazioni che il Congresso è stato chiamato a discutere.

Gli autori delle varie teorie sugli spostamenti continentali, ad eccezione del Taylor, insistono con vivacità sull'attitudine di esse a spiegare in modo semplice e facile le oscillazioni climatiche per cui sono o si presumono passate le varie parti del mondo. E particolare insistenza si fa a tale proposito sulle espansioni glaciali. È noto, infatti, come Wegener e Köppen (2), combinando la deriva delle masse continentali con ipotetici spostamenti dei poli terrestri di rotazione, abbiano cercato di attribuire i depositi glaciali di ogni periodo ai climi freddi dominanti nelle alte latitudini: là dove furono regioni di glaciazione nel corso dei tempi geologici, furono regioni polari; variando

soltanto la intensità delle glaciazioni a seconda delle condizioni topografiche e altimetriche e dei fattori astronomici agenti come cause del tutto subordinate. Nel medesimo senso si esprimono tutti coloro — dall'Argand al Gutenberg ([3]) e al Van Waterschoot Van der Gracht ([4])—che seguono il Wegener o che ne hanno più o meno profondamente modificata la teoria; e il movimento delle idee su tale riguardo si è venuto man mano accentuando negli ultimi anni.

È un fatto singolare, tuttavia, che per illustrare e documentare queste vedute si ricorra quasi esclusivamente alla glaciazione permocarbonifera, senza spiegare perchè le calotte glaciali nel corso dello stesso Permiano siano così presto e definitivamente scomparse, e lasciando in disparte, cosa più singolare ancora, la glaciazione pleistocenica. Anche Wegener è venuto modificando le sue prime vedute in proposito. Leggiamo infatti nell'ultima edizione della sua opera capitale, pubblicata quest'anno, che le cause della glaciazione quaternaria devono essere lasciate per intero fuori della discussione, per essere nel Quaternario la posizione dei continenti così prossima all'attuale, da non potersene trarre che deboli criteri paleoclimatici per la teoria della deriva ([5]): cioè, in altre parole, per non potersi spiegare con la teoria stessa la glaciazione pleistocenica.

In modo analogo, R. Staub, ([6])—che degli spostamenti continentali, sviluppando le idee di Argand, ha saputo dare una rappresentazione nuova, più persuasiva e meglio rispondente ai fatti geologici accertati,—basa le considerazioni paleoclimatiche essenzialmente sulle tilliti permocarbonifere, ritenute testimonianza di clima polare, e sui depositi di carbon fossile, ritenuti prova di clima tropicale; estendendo poi il suo quadro agli altri periodi, trova nelle tilliti algonkiane e devoniane argomenti per confermare la periodica risalita dei continenti nelle alte latitudini; ma la glaciazione quaternaria è passata anche da lui sotto silenzio. Anche per lui è dunque necessario ricorrere, per questa, ad altre spiegazioni.

In realtà, troppo gravi ragioni ci costringono a concludere in questo modo. Basti ricordare: l'estensione della glaciazione pleistocenica a tutti i continenti ed a tutte le latitudini, per quanto in grado e misura diversi a seconda della posizione geografica e dell'altimetria; la contemporaneità pressochè accertata del periodo pluviale nelle zone più depresse ed a più basse latitudini con il periodo glaciale nelle zone montane e nelle latitudini più alte; le testimonianze, ormai riconosciute in tutti i continenti, di due principali fasi di espansione glaciale separate da un grande interglaciale a clima verosimilmente più caldo dell'odierno, e la seconda di esse suddivisa a sua volta da un interglaciale secondario: fatti e circostanze che sopra tutto la scuola di Vienna ha contribuito a mettere nella luce dovuta.

Tali considerazioni inducono seriamente a riflettere se sia proprio esatta l'interpretazione che sempre più estesamente tende oggi a diffondersi circa

l'estensione e le cause delle glaciazioni prequarternarie. L'esame può farsi con una certa cura coltanto per le espansioni permocarbonifere, che sono meglio conosciute; ma i risultati dell'esame e della discussione hanno una portata più generale. E si nota, in effetto, quanto segue:

1. Testimonianze di glaciazione antracolitica sono state trovate non soltanto nelle terre circostanti all'Oceano Indiano e in parti svariate dell'-America meridionale, ma altresì nell'Africa centrale (bacino del Congo) e nord-occidentale (Togo), nel Salt Range, nel Baluchistan, nell'Afghanistan, nell'Alaska, nella Nuova Scozia, nel Massachussetts, nell'Oklahoma, nel Colorado e nel Kansas ([7]).

2. Se prendiamo per base l'ipotesi di Wegener, vediamo distribuirsi le prime di tali regioni nell'interno di una enorme massa continentale, in posizione prossima al polo antartico, ma così interna da doversi considerare almeno in parte arida o subarida; vediamo altre di tali regioni situate a latitudini molto basse, fra 30° e 10°. Wegener e Van der Gracht replicano che i depositi segnalati come morenici in queste ultime zone, in parte non devono essere glaciali e in parte devono esser dipendenti da ghiacciai montani ([8]). Ma la prima asserzione, certo assai comoda, ha bisogno di essere dimostrata; poichè non basta, evidentemente, dire che la natura glaciale di quelle tilliti è inconciliabile con le tracce climatiche di opposto significato, sopra tutto quando tali tracce non sono contemporanee alle tilliti ed è controverso il loro significato. E la seconda asserzione, neppur essa dimostrabile, anche se esatta basterebbe già a denotare condizioni climatiche diverse dalle normali, eliminando così la possibilità di spiegare quei depositi glaciali con i soli spostamenti dei blocchi continentali e dei poli. Del resto, le tilliti indubbiamente glaciali dell'Afghanistan, a una latitudine che sarebbe stata di 30°, si alternano con depositi marini; cosicchè si tratta di ghiacciai discesi fino alla spiaggia.

3. Se prendiamo invece per base l'ipotesi dello Staub, i contrasti appaiono meno stridenti; ma ci troviamo sempre con depositi glaciali in regioni e latitudini dove essi non sono possibili in condizioni climatiche normali. Infatti, benchè la teoria dello Staub non sia ancora sufficientemente elaborata in riguardo alle ricostruzioni paleogeografiche, sembra dal contesto che le tilliti dell'Africa nord-occidentale si sarebbero formate a una latitudine prossima ai 40° S, e quelle dell'Afghanistan a latitudine notevolmente più bassa. Altrettanto deve dirsi per i depositi riscontrati nel Colorado, nel Kansas, e più ancora nell'Oklahoma, non ostante che sulle posizioni assunte dall'America settentrionale durante il Carbonifero e Permiano si trovino nello Staub indicazioni assai vaghe.

4. Il problema è aggravato dal fatto che, mentre la maggior parte dei depositi glaciali antracolitici è del Permiano inferiore, taluni di essi risalgono invece (così il Coleman) al Carbonifero superiore ed anche al Carbonifero

medio. I problemi si intrecciano e si complicano, sfuggendo così ad ogni tentativo di soluzione con i semplici movimenti delle masse continentali.

D'altra parte, queste considerazioni ci fanno ritornare al pensiero perfettamente logico che aveva ispirato per lungo tempo i precedenti tentativi di sciogliere l'enigma glaciale: che cioè devono essere state le medesime cause a produrre i medesimi effetti; devono essere state le medesime cause a determinare così le espansioni glaciali quaternarie come le espansioni glaciali prequaternarie.

Non il più piccolo indizio si può trovare che denoti diversità di principii nelle manifestazioni di questi fenomeni, che tutto dimonstra invece essersi ripetuti in maniera analoga in vari tempi della storia del globo. È soltanto per la nostra miglior conoscenza della glaciazione quaternaria, così prossima a noi e così nettamente testimoniata dalle sue visibilissime tracce, che facilmente è caduto ogni tentativo di spiegazione in cui si prescindesse da mutamenti climatici generali. Ora non soltanto nessuna ragione vi è che permetta di supporre un diverso andamento dei fenomeni nel passato; ma anzi vi sono, e l'abbiamo visto, fatti e circostanze che proprio dimostrerebbero la stretta analogia della glaciazione antracolitica con la pleistocenica.

La ricerca delle cause ritorna, così, al punto in cui fu impostato magistralmente il problema da W. B. Scott ([9]); ma vi ritorna sotto una luce alquanto diversa. Lo Scott aveva riassunto le varie ipotesi in uno schema assai chiaro e comprensivo:

I. Cause terrestri.

A. La Terra nel suo complesso.

1. Variazioni nell'eccentricità dell'orbita.
2. Variazioni nella quantità delle ceneri vulcaniche sospese.
3. Spostamento della parte esterna della Terra rispetto all'interna.
4. Diminuita influenza del calore interno del globo.

B. Fattori atmosferici.

1. Variazioni nella proporzione dell'anidride carbonica.
2. Variazioni nella quantità delle ceneri vulcaniche sospese.

C. Fattori oceanici.

Variazioni nella salinità.

D. Fattori topografici.

Cambiamenti nell'estensione, nell'altitudine e nella disposizione delle masse continentali.

II. Cause cosmiche.

A. Passaggio attraverso regioni fredde dello spazio.

B. Variazioni dell'attività solare.

Una breve ma serrata discussione conduceva lo Scott a respingere come non resistenti alla critica la maggior parte di tali ipotesi, a respingerne altre come insufficienti, e ad adottare per eliminazione quella che Huntington ha chiamato ipotesi solare dei mutamenti climatici ([10]), e di cui l'idea prima risale a Lord Kelvin. Ipotesi che naturalmente non esclude altre cause concomitanti, e che anzi si armonizza bene con le cause insite specialmente nei cambiamenti di estensione, configurazione e altitudine delle terre emerse, per quanto Simpson ([11]) tenda a ridurre in limiti forse troppo ristretti l'effetto ad esse imputabile. Ritengo che sopra tutto non debba essere trascurato il fattore orogenico; poichè è ben noto che ogni glaciazione fu successiva a un periodo di intenso corrugamento ed elevazione di grandi catene montuose e di epeirogenesi, connesso in generale con un attenuarsi del vulcanismo.

Ma queste cause, che vorrei chiamare meglio predisponenti che secondarie, sono a loro volta intimamente associate e legate a quella della distribuzione delle terre emerse, in dipendenza della deriva dei continenti. Deriva che l'evidenza dei fatti e fenomeni geotettonici ci costringe ad ammettere, e che l'ipotesi di Staub permette di coordinare (almeno provvisoriamente) in un sistema meglio di altri resistente alla critica.

La deriva dei continenti, con le sue conseguenze geografiche e orografiche, deve pertanto essere considerata come la causa più efficace a predisporre le grandi invasioni glaciali; ma queste non si spiegano nella loro generale estensione e nei loro caratteri, senza ricorrere, come causa determinante, alle variazioni dell'attività del Sole.

NOTA.—Il recentissimo lavoro di L. J. Krige *Magmatic cycles, continental drift and ice ages* (Proc. geol. Soc. South Africa, 1929), che ho conosciuto soltanto dopo l'invio del manoscritto alla Segreteria generale del Congresso, non mi persuade a modificare tali conclusioni. Partendo dall'ipotesi dei cicli magmatici di Joly e Holmes (che riconduce i diastrofismi terrestri alla periodica fusione degli invogli simatici per l'accumularsi del calore liberato dalla disintegrazione delle sostanze radioattive), ipotesi combinata con la teoria delle traslazioni continentali da Waterschoot van der Gracht, il Krige ferma l'attenzione sul calore di origine terrestre che l'ipotesi stessa suppone periodicamente riversato nell' oceano. E richiamandosi alle vedute teoriche del Simpson, per cui un *aumento* del 20% nella radiazione solare potrebbe determinare una invasione glaciale per effetto dell'aumentata evaporazione, il Krige pensa che un simile risultato potrebbe anche esser prodotto dal flusso di calore terrestre restituito sui fondi oceanici dalla consolidazione di un invoglio peridotitico di 200 km. di spessore. A parte le riserve sul principio del Simpson e sulla teoria di Joly-Holmes, la nuova spiegazione delle ere glaciali non mi sembra sostenibile per più ordini di ragioni: (1) la teoria dei cicli magmatici non risponde ai dati della geologia storica, come ho dimostrato nel già citato lavoro di geotettonica; (2) un aumento di evaporazione dipendente da calore terrestre, cioé da un flusso centrifugo di calore, avrebbe conseguenze ben diverse da un aumento di evaporazione determinato da aumento della radiazione solare cioè da una causa esterna; (3) l'aumentata temperatura superficiale degli oceani non potrebbe procedere che da aumento di temperatura dei bacini oceanici, in misura tale da modificare, migliorandoli, i climi, e da modificare profondamente l'ambiente biolo-

gico marino, con conseguenze formidabili di cui la paleontologia non in fornisce la più piccola prova.

(1) GORTANI M., *Ipotesi e teorie geotettoniche* (estr. dal Giorn. di Geologia, Ann. d. R. Museo geol. di Bologna, III), 1928.

(2) KÖPPEN W. E WEGENER A., *Die Klimaten der geologischen Vorzeit.* Berlin, 1924.

(3) GUTENBERG B., *Die Veränderungen der Erdkruste durch Fliessbewegungen* (Gerlands Beitr. z. Geophysik, XVI e XVIII), 1927. L'ipotesi di Wegener è qui modificata supponendo che il grandioso continente unico, in luogo di smembrarsi in singole zolle allontanantisi l'una dall'altra, si sia soltanto esteso per stiramento; gli oceani Atlantico, Indiano e Artico corrisponderebbero alle parti più assottigliate nello stiramento.

(4) VAN WATERSCHOOT VAN DER GRACHT, *The problem of continental drift* e *Remarks regarding the papers offered to the symposium* (in "Theory of continental drift," a symposium, Amer. Ass. Petroleum Geol.), Tulsa, 1928. L'ipotesi è qui combinata con quella della radioattività secondo Joly.

(5) WEGENER A., *Die Entstehung der Kontinente und Ozeane,* Braunschweig, 1929 (IV ediz.).

(6) STAUB R., *Der Bewegungsmechanismus der Erde,* Berlin, 1928. Secondo lo Staub, i due aggruppamenti fondamentali di terre, Gondwana e Laurasia, si muovono alternativamente in due direzioni opposte: si alternano cioè, nella storia della Terra, un movimento di deriva verso l'equatore (che è determinato dalla forza centrifuga e che, nell'affrontarsi reciproco dei due immensi continenti, porta all'orogenesi) e un movimento di deriva verso il polo (che è determinato da correnti subcrostali e che porta a stirare e deprimersi la zona dei mediterranei).

(7) Cfr. COLEMAN A., *Permocarboniferous glaciation and the Wegener hypothesis,* Nature, 1925;—Id., *Late palaeozoic climates,* Amer. Journ. Sci., 1925;—BROOKS C. E. P., *Climates through the ages,* London, 1926, cap. XIV;—SCHUCHERT CH., *The hypothesis of continental displacement* (in "Theory of continental drift, cit.), 1928.

(8) WEGENER A., *Two notes concerning my theory of continental drift* (in "Theory of continental drift," cit.), 1928;—VAN DER GRACHT, *Remarks* ecc., cit.

(9) SCOTT W. B., *Geological climates.* Presidential address (Bull. geol. Soc. Amer., XXXVII), 1926.

(10) HUNTINGTON E., *The solar hypothesis of climatic changes* ,Bull geol. Soc. Amer., XXV), 1914.

(11) SIMPSON G. C., *Past climates* (Quart. Journ. Roy. meteor. Soc., LIII) 1927.

ABSTRACT.

According to HUNTINGTON, SCOTT, etc., glaciations on a continental scale can be caused only by variations of the sun's activity. In these last few years, the authors of continental drift theories insist more and more that we must look for the principal cause of changes in earth's climates in the displacement of continental masses, with or without changes in the position of the poles. But neither WEGENER's and KÖPPEN's hypothesis, nor GUTENBERG's "Fliesstheorie," nor STAUB's "Bewegungsmechanismus der Erde" can explain the pleistocene glaciation, especially on account of its manifestation in all the continents together with its great interglacial fluctuations.

On the other hand, we cannot find in this hypothesis the primary explanation of prequaternary glacial periods, because (1) tillites of the same epoch have been found near the supposed poles as well as far from them, (2) no fact proves that prequaternary

glaciations were essentially different from the pleistocene glaciation, (3) it would be unreasonable to assume entirely different causes for very analogous phenomena, and finally (5) it is logical to believe that climatic fluctuation like that of the Quaternary may have taken place also in the previous history of the earth.

Continental drift (which I accept only with circumspection and in the same sense as Staub) is merely one of the terrestrial agencies which may be united with the cosmical causes in modifying the earth's climates.

10. AN OCCURRENCE OF LATE PALAEOZOIC TILLITE IN THE KURUK-TAGH MOUNTAINS, CENTRAL ASIA

by

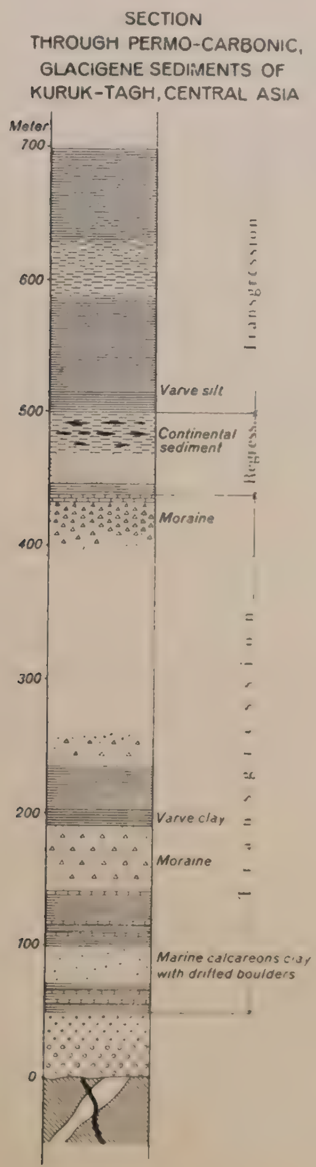
Erik Norin,

(Geologist to the Sino-Swedish expedition under the leadership of Dr. Sven Hedin and Professor Siu-p'ing-chang.)

In the summer of 1928 a new locality of glacial sediments and moraines of late palaeozoic age was discovered in the mountain ranges of Kuruk-tagh, which border the Tarim basin to the north between long. 88-90° lat. 40-42°N.

The fundament of the glacial formation consists of gneisses with metamorphosed coal seams, probably of lower carboniferous age, which are strongly folded and intruded by large bodies of coarse grained granite and nepheline syenites. Another unconformity delimits the glacial formation upwards and separates it from a thick series of marine limestones and shales, rich in fossils probably of permian age. Therefore a permo-carboniferous age of the sediments included between these two unconformities has been provisionally assumed.

The thickness of this formation exceeds 700 m: the succession of strata is shown on the accompanying section. Generally it is slightly dislocated only. Thermal metamorphism has been observed only locally. The lower part of the complex (0-500m) consists of beds of marine calcareous clay with drifted boulders and also true moraines, each 30-100m. thick, alternating with beds of gray and black shales without glacial boulders. At places the moraines are overlaid by beds of annually laminated clay shale which grades upwards into marine black shales with a few drifted boulders. The uppermost horizon of these glacio-marine beds is a very thick bed of moraine from which numerous, large boulders showing distinct glacial striation have been collected. This moraine is conformably overlaid by a bed of marine limestone, which grades upwards into marine shallow water deposits and continental, coalbearing sediments some 30m. thick. These continental sediments correspond to a temporary recession of the sea. It was followed by renewed subsidence, which is registered by a thick series of glacio-marine delta deposits. The lower part of this formation consists up to a thickness of



150m. of a very homogenous series of greyish green laminated silt. Throughout this great thickness the character of the layers is very uniform. It is a regular alternation of coarser, light greyish green silt and very fine grained, rather dark, grey clayey silt forming varves averaging 1 cm. in thickness. Drifted glacial boulders have not been observed. At higher levels calcareous material begins to appear forming the transition into a series of marine limestones.

The texture of the sediments and the distribution of the glacial formation as revealed in the geological map of the region, suggest that the sediments have been accumulated in a broad valley. This valley originated in the "Tarim oldland" and was directed towards the north. The Kuruk-tagh region formed the northern shore of this oldland and here the glaciers from the interior reached the sea.

The investigation of the glacial sediments of the Kuruk-tagh ranges will be continued during the autumn of 1929.

Stockholms Högskolas Geokronologiska Institut, May 1929.

11. ON A PROBABLE TILLITE OF LATE-PALAEOZOIC AGE FROM THE KARA-RIVER, NORTHERN-MOST URAL.

BY

HELGE G. BACKLUND
(Upsala.)

PROFESSOR F. V. HUENE, of Tübingen, has recently given a review of the Karroo of South Africa (1) in which he discusses the evolution of geological and faunistical elements constituting this interesting formation.

He mentions also the famous discoveries of the Karroo flora and flora of the Upper Permian in northern Russia (*Amalalitzky* (2) *Riabinin* 1924 (3) and points out the close connection of their faunistic elements, especially of the vertebrates, with those of the South African lower Beaufort series. The ways in which the interchange of fauna and (glossopteris-) flora had been performed he does not touch upon; however these allied elements of the Upper Permian of Europe (*p.e.* Scotland), were always a matter of speculation.

One is still disposed to seek a connection of these faunas and floras with postglacial conditions of climate in analogy with the South African localities, *i.e.* with a late palaeozoic glaciation. At several times there were announced tracks of a glaciation of these times from the Ural mountains, but the final confirmation is still outstanding.

Therefore the preliminary report of E. NORIN (4) on glacial sediments and moraines of late palaeozoic age discovered in mountain range of Kuruk-tagh, central Asia, deserves the greatest attention. These sediments, whose thickness exceeds 700 m., repose unconformably on a strongly folded and granite intruded series of coalbearing gneisses, to which the author attributes a lower carboniferous age; they are limited upwards by another unconformity, which is crowned by a slightly disturbed thick series of marine limestones and shales rich in fossils probably of Permian age. The author concludes a permo-carboniferous age of these intercalated glacial sediments, which were deposited in a broad valley under prevailing marine conditions. The origin of the material he derives from the "Tarim Oldland" and the direction of drift was northward. It is quite clear that the tracks of this ancient glaciation, whose detailed description may be looked for with

greatest interest, cannot be discussed directly in connection with the appearance of the upper Permian fauna (and flora) of the Upper Dwina and Eastern Russia in general. But they certainly induce some considerations upon the evolution of land and sea areas during the late Palaeozoic eras in the region of the Ural mountains.

The writer had the opportunity to visit, in 1909 the northern end of the Ural chain, close to the Kara Sea. The description of this expedition, with a petrographic monograph of a part of rocks collected on the eastern slope of northermost Ural appeared in 1911/12/5; the further description of the geology of the area visited was combined with a monograph of the geology of the Siberian north coast (5). Then the further studies were interrupted by circumstances of war. Through the courtesy of MR. B. KUPLETSKI of Leningrad the writer anew got connection with collected material, specially with microscopic rock slides of the Ural expedition. The following pages may be considered as impelled by the communication of DR. NORIN, the outlines of the geology and the importance of the sediments described below having been received already in 1909 and tentatively discussed with TH. TSCHERNYSCHEW.

The northern end of the Ural mountains is cut by a strike fault running WNW-ESE. The southern limb stands out from the flat northern tundra just like a wall and constitutes the steep slopes of the Konstantinow Kamen, Minisey a.o. mountains. Their rock is a thick-bedded, coarse, reddish quartzite probably of Devonian age. The fault is accentuated by broad conformable dikes of gabbroid diabase outcropping in the plain below, which in general is covered with heavy deposits of the latest glaciation. These glacial and glaciofluvial coverings govern the morphology of the plain, the outcrop of older rocks being scarce and only occasional. The next continuous outcrops one meets with in the Kara river cañon, on the ancient boundary between Europe and Asia. They represent a series of bright dolomite, red cherty slates, grey limestones with cherty nodules, quartz veined black slates and calcite veined dark limestones, all strongly folded together and standing nearly vertically. The isoclinal folding appears downward, in northern direction and several overthrust folds were also observed. The series is poor in determinable fossils; its northernmost and probably youngest member contains *Fusulinidae* and some indeterminable *Productus* casts. The top of the formation may therefore be of upper Carboniferous age. The river is sharply winding through this series of rocks with general western trend, cutting through the cherty ones in northerly short ruggy couloirs with numerous rapids, and bending westward in long quiet limbs at the entrance amidst rocks of lesser resistance.

At 27 km. exactly S. of the inner delta of the Kara river and at about 43 km. south of the Kara Sea shore close to the outer river mouth, on the last great western bend of the river, at 68°52'N. and 64°45' E. of Greenwich

(cf. map in (5), the picture of the rock formation changes abruptly. Unconformably on the top of the vertical beds of the dark limestone there reposes a thick series of what could be named polymict breccia. The elements of this breccia change from a sandy grit to angular boulders several meters in diameter and are very irregularly distributed throughout the outcrop. There are also subangular and rounded boulders met with, and some of them are distinctly striated. The formation is disposed so as to form vertical walls and pillars covered with great top boulders. The total thickness of this formation is difficult to estimate because of its uneven floor. The dark limestone of the floor is projecting through the formation at several points on the upper part of the outcrop. A rough estimate gives some 50 m.

The material of this formation is, as mentioned, polymict and cannot in general be derived from the floor rocks, whose section was shortly described above. There are sandstone boulders in it containing abundant felspars and chips of thinly laminated slates with small scales of a dark mica, which are not represented in the underlying series. The red cherty (jaspilitic) shales seem to be lacking absolutely; only some boulders of impure limestone may perhaps belong to some of the varying limestones of the bed rock series. Some boulders of a green, strongly serpentinized and chloritic rock may perhaps originate from some igneous complex, whose parents were met with upstreams, at the southern part of Palaeozoic rocks section; at that outcrop this rock represents the character of a strongly epidotized melaphyre. The dark slate chips show some resemblance to a rock on the Kara Sea shore (*cf.* below.)

The impression of this formation is strongly that of a moraine (tillite). Upward the boulders become scarce, and the grey rough deposit is replaced by a smooth and regularly laminated clayish sandstone and banded claystone which could fully justify a determination as glaciofluvial deposits. The series is slightly disturbed with a northern dip of the strata. The last outcrop of this series is represented by conformable bituminous shale, which soon disappears beneath the tundra cover. On the Kara Sea shore, at Cap Tolstoj ("Polkownik") a black shale of another habit, with small calcite veins, forms the last small, but steep seaward escarpment; the dip is here southward. This rock reminds one strongly of the black shales described by HOLTEDAHL (7) from the eastern entrance of the Matochkin strait, at the northern island of Novaja Zemlja. HOLTEDAHL ascribed to them an Artinsk age. Between these two lastnamed localities on the Kara river there were met with some isolated outcrops of igneous rocks of the diabase parentage on a tundra hummock; the relations of it to the north and south were obscured by late glacial and recent coverings.

For fixing the age of this supposed glacial ("tillitic") formation it may be safer to try a short orientation on the geologic history of Northern

Ural. The head folding of the Ural mountains occurred during the "Saale" stage of STILLE (8), i.e., after the permocarboniferous (Artinsk) deposits were laid down, because they were folded together with the upper Carboniferous limestones. The age is defined as lower Permian. KULIK (9) has shown that a slight folding endured through the Upper Permian, and conformably herewith MASAROVICZ (10) has traced persistent continental pebble horizons in the Lower Triassic, strewn over great areas between the middle Wolga and Ural. The mode of their occurrence shows that there were no distinct river beds enclosing them; strongly fluctuating seasonal waters under nearly desert conditions governed their deposition. Yet land conditions may have prevailed in some northern parts of the Ural, because in the eastern part of the Bolshezemelskaya tundra later mesozoic deposits seem to repose directly on the Upper Carboniferous (SOKOLOW (11)). Certainly the sea conditions of the Lower Permian seem to have deteriorated at the western slope of Northern Ural, because as pointed out lastly by SOSCHKINA (12) the marine animal life distinctly declined and specially the coral fauna shows clear signs of degeneration perhaps by the rising mud content in the sea water as a consequence of increasing land conditions in the east, as supposed by the cited author, or by the change to the worse of the climatic conditions alternately.

In consequence of the statements made by G. FREDERICKS (13) and the cited authors an increase of the land conditions may be established from the beginning of the Permian throughout to the Lower-Middle Triassic; conformably herewith the conditions of glaciation increase. Yet as no Triassic deposits of the Ural border show any but gentle broad folding (ARCHANGELSKY (14)) at some distance of the chain, and banded and conglomeratic ("tillitic") deposits on the Kara river are more than broadly folded, their age may be earlier than the Upper Permian ("Palatinat" stage of STILLE (14)) but later than the Artinskian (Permocarboniferous); it falls inside the early Permian.

But why were there no definite earlier discoveries of late Palaeozoic glacial deposits in the Ural Mountains? There are two tentative answers to this question. Perhaps the north-south trending chain of Ural has undergone such a degree of denudation, that there have remained not even the roots of this formation. That is an easier form of answer. More probably perhaps the north-south trending chain of the Ural does not append to any old land to the west; probably also to the east its Caledonian forerunner was limited by sea conditions since Devonian and perhaps earlier times. In the north, the westward trending branch was probably limited to the north by a water condensing high oldland, constituting nowadays the Kara sea (15).

Therefore there may be a chance to look for late Palaeozoic glacial deposits on the Novaya Zemlja islands, and perhaps, on the mountain ranges

encircling the Kara Sea from the south and from the east; i.e. on the Taimyr Peninsula and on the Nicholas II Land; supposed that these ranges are of Late Palaeozoic age (16). It may be pointed out that all expeditions which have brought home geological material from the northernmost point of Asia, succeeded in registering a polymict conglomerate of uncertain geologic position from that point.

In conclusion some parallels above touched on may be relieved: in Southern Africa during pre- and lower Dwyka times the material of (Devonian a.o.) sedimentation arose from the south, then in late Dwyka it turned from the north. In Northern Russia the Devonian sediments are transported from the west, during the Permocarboniferous and Permian the sedimentation was inverted, the material coming from the east. After this performance the evolution of the Karroo began. Huene points out some decidedly American elements in the Russian Karroo: it may be enough to point to the recent discoveries at Connecticut of deposits probably pertaining to a late palaeozoic glaciation.

The Arctic and its past conditions are still full of problems. The foregoing pages are written with intention to turn the attention on some of them, and to induce the Russian colleagues, to whom the geology of the Palaearctis owes many elucidations along the Siberian coast, to undertake a revision of what was here described and pointed out. Therefore the location is given as exactly as possible. And the discovery of Dr. Norin together with the few facts given above may serve as a contribution to the great problem of migration, or evolution, of animal life from pole to pole by means of land-bridges, by continental drift or by pendulations of the poles.

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12. PRE-CAPE TILLITES IN THE UNION OF SOUTH AFRICA.

BY

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This note on the Pre-Cape tillites is written for the purpose of drawing attention to the occurrences; they have all been described in print, with the exception of some exposures of the tillite in the Witwatersrand System in the Klerksdorp district, so I do not propose to repeat the descriptions.

The youngest of these tillites is that in the Transvaal System, which was first recorded in the Griquatown beds of Griqualand West and Bechuanaland, and was afterwards found in the correlated Pretoria Series. The area over which this tillite has been seen is very considerable, 250 miles from north to south and 320 miles from east to west. The most striking feature in connection with it is the absence of such igneous rocks as granite and gabbro or dolerite, and in this respect it resembles the tillite in the Witwatersrand formation. The pebbles and boulders are of cherty rocks, limestones, quartzites, quartz and amygdaloidal igneous rocks of intermediate composition, the source of which is not known.[1])

In the Witwatersrand System a tillite has been recorded from the Government Reef Series in the Heidelberg and Klerksdorp districts, while on the Witwatersrand itself argillaceous beds on the same horizon are known to contain scattered pebbles of large size, but the beds are not well exposed.[2])

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[1]) The description of the outcrops will be found in:—

Ann. Report of the Geol. Commission, Cape of Good Hope, for 1905, pp. 162-4, 167, 170-1.

Ann. Report of the Geol. Commission, 1906, pp. 42-3.

Ann. Report of the Geol. Commission, 1907, pp. 62-3.

Report of S.A. Ass. for the Adv. of Sci. for 1906, pp. 260-5.

Trans. Geol. Soc. S. Africa IX, 1906, pp. 8-9.

"Geology of Cape Colony," 2nd Edition, 1909, p. 96.

A. L. DU TOIT: "Geology of South Africa," 1926, p. 95 and 109.

L. J. KRIGE: "Explanation of Sheet 1 (Transvaal), 1929, p. 17.

[2]) "The Geology of the Neighbourhood of Heidelberg." Trans. Geol. Soc. S.A. XXIV, 1921, pp. 17-52, especially p. 23. Explanation of the Geological Map of Heidelberg, 1922, p. 20. In Klerksdorp the tillite can be seen on the farms Buffelsdoorn, No. 660; Rietfontein, No. 632; and Palmietfontein, No. 697.

The Numees series of Namaqualand includes a remarkable tillite which was first recorded by ANDREW WYLEY in 1857 as an example of the effects of metamorphism, for he took the sheared boulders of granite to indicate the initial stages in the production of gneiss. At the same time he noted the close resemblance between the Numees rock and what he called the Trap Conglomerate in the Karroo, now known as the Dwyka Tillite. The resemblance emphasized by WYLEY is certainly striking. The Numees tillite contains a variety of boulders of sedimentary and igneous rocks, but volcanic rocks have not been recorded from it.[3])

The age of the Numees tillite is still in doubt; in the paper of 1915 the beds were regarded somewhat doubtfully as of Nama date, but observations on the right bank of the Orange River indicate that they must be considerably older. As to their age relatively to the Witwatersrand beds there are at present no facts worth discussing.

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[3]) ANDREW WYLEY: Report upon the Mineral and Geological Structure of South Namaqualand. Cape Town, 1857, (G. 36-'57), p. 5 and p. 22.

Trans. Geol. Soc. S. Africa XVIII, 1916, pp. 72-101, especially p. 77 and 89-93.

13. THE GLACIAL BEDS IN THE TABLE MOUNTAIN SERIES.

BY

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Introduction.

The occurrence of a glacial conglomerate in the Table Mountain Series was first described by ROGERS in 1901 (Trans. S. Af. Phil. Soc. XI, p. 236 et seq.) who gave an account of its distribution in part of the Clanwilliam Division in the neighbourhood of Pakhuis Pass. The conglomerate occurred there on an horizon known as "the shale band" — now called "the Upper Shale Band" — whose limits had previously been defined by SCHWARZ.

In 1904 ROGERS gave a further account (Trans. S. Af. Phil. Soc. XVI, p. 1 et seq.) of the distribution of the conglomerate on the northern and western sides of the Cedarbergen; and in 1906 SCHWARZ gave a summary of the then-known facts (Journ. Geol. 1906, XIV, p. 686 et seq.).

In 1908 DR. BROOM found striated pebbles in the sandstone of Maclear's Beacon, Table Mountain.

No further investigations were recorded until 1925, when a joint paper by HAUGHTON, KRIGE and KRIGE (Trans. Geol. Soc. S. Af. XXVIII, p. 19 et seq.) described the occurrence of tillite at several localities in the Western Province, together with strong intraformational folding in the sandstones just below the Upper Shale Band, the folding being interpreted as due to the actual movement of ice over unconsolidated sands. RENNIE (Trans Geol. Soc. S. Af. XXVIII, pp. 79-80) in the same year described briefly an apparently similar occurrence on Table Mountain. DU TOIT (Geol. of S. Africa, 1926, p. 179) summarised our knowledge at that date and gave a first account of the tillite at Michell's Pass, Ceres.

Extent and Nature of the Deposit.

From Pakhuis Pass — the point where it was first discovered — the glacial band has been traced at a number of localities as far south as Gordon's Bay, a distance in a north-south direction of about 120 miles; whilst the most easterly point at which it has been identified is the Zwarteberg Pass, which is 210 miles east of the latitude of Table Mountain.

In the Cedarbergen around Pakhuis and for some 20 miles southwards the Upper Shale Band is some 300 feet thick and is overlain by about 1500 feet of sandstone.The lowest third of the Shale Band consists of greenish-blue or reddish mudstone without lamination containing scattered pebbles and boulders of quartz, quartzites, sandstones, hard grits, felsites, red jaspers, amygdaloidal diabase and granite, which are distributed throughout the matrix in a random manner irrespective of size. A fair proportion of the boulders and pebbles shew flattened and striated surfaces with facetted edges, whilst many of them — especially the smaller ones — are well rounded and similar in shape to those found scattered through the main mass of the Table Mountain Sandstone. The glacial band passes here upwards into shale by a decrease in the number of inclusions and the appearing of lamination planes. Rogers recorded that on Bosch Kloof the passage from the usual coarse quartzitic sandstones of the Table Mountain Series into the glacial band was a narrow one; but south-east of the Cedarberg Tafelberg an exposure on the left bank of the Matjes Rivier shews an unconformity at the base of the Upper Shale Band with intraformational folding of the sandstones lying beneath the undisturbed glacial band, similar to the occurrences further south.

Between this point and Michell's Pass in the Ceres District the glacial band has not been traced in detail. In Michell's Pass the tillite is well exposed in a railway cutting south of the road-crossing. Here the Table Mountain Series dips at about 50° to the north-east and the Upper Shale Band forms a prominent grassy slope easily distinguishable from the steep escarpment faces of the jointed sandstones which build the mountain masses. The tillite occurs at the base of the Upper Shale Band, which is about 150 feet thick and formed of somewhat sandy shales. These pass downwards into some 20 feet or more of a dark bluish-green cleaved mudstone, unbedded and carrying small pebbles and quartz grains, and this in turn into a white-weathering, bluish-green unbedded, cleaved gritty sandstone which carries isolated pebbles mainly of quartz and quartzite, up to a foot in length, and well striated and facetted. This band is some 50 feet thick and passes downwards into normal sandstone.

One of the finest exposures of the glacial beds as yet examined occurs on the broad long ridge which joins the peaks of Brandwacht and Fonteinjesberg in the mountain mass N.N.W. of Worcester, and which separates the Jan du Toits Kloof from the head-waters of Fairy Glen. This ridge is at a height of about 6000 ft. above sea-level. From it the Upper Shale Band has been denuded; but it appears to the east as the rim of a basin along the Meiring Plateau and the slopes of the Meiring Ridge Peaks. The glacial beds on the ridge are conspicuous by their weathering. In general they are redder or darker in colour than the underlying sandstones, are unbedded or unevenly bedded, and tend to weather into upstanding

slabs and pinnacles of rock. The rock has an uneven floor, resting as it sometimes does in the hollows of the synclinal folds of the disturbed strata below it. The matrix is almost wholly quartzitic; the inclusions vary in size, but are largely quartzitic — although some shaly inclusions and a large one of quartz-sericite-chlorite-rock were seen. Many of the well-rounded inclusions have flattened surfaces, and a number of them are beautifully scratched and grooved. The rock is very similar to that seen elsewhere at the same horizon in the Western Province Mountains.

Tillite of a similar nature also occurs at the base of the Upper Shale Band along the mountain range which bounds the northern side of Buffels Kloof in the Hex River Mountains, and is visible on the same horizon in the Matroosberg area.

In the Slanghoek Mountain mass, lying to the east of Wellington, the Upper Shale Band forms a very conspicuous feature, and the relationship between it and the glacial beds has been examined on the peaks known as the Wellington Sneeuwkops (Upper and Lower.) The most striking phenomenon here, and in neighbouring areas, is the intraformational folding which affects nearly 300 feet of the sandstones below the Upper Shales. These latter are about 130 feet thick, and composed of greenish micaceous well-bedded shales with sporadic elongate lenses of soft shaly sandstone. Almost at the base is a persistent layer — the so-called "Hard Band" — which has almost the appearance of normal pebbly Table Mountain Sandstone, but contains pebbles of varying size sometimes closely set together to form a conglomerate. Some of the pebbles are soled and facetted and a few have striated faces. Below the "Hard Band" are several feet of tillite — a rock composed of pebbles set in a matrix which is mostly arenaceous but sometimes argillaceous. The latter variety weathers brown, but is bluish-green when fresh. Many of the pebbles are flattened in outline and have opposite faces planed off flat; some carry unmistakable scratches and striations. Further, the tops of the anticlines in the disturbed sediments below the tillite are usually truncate, and the hollows in the synclines are filled with tillite.

In the Hottentots Hollands Mountains, near Stellenbosch, similar features were described by Krige and Krige. Here the Upper Shale Band is about 150 ft. thick, the "Hard Band" is present at its base, and intraformational folding below it is conspicuous. The tillite which lies in the synclines below the "Hard Band" is an unstratified rock which weathers brown and assumes tombstone-like forms, strongly resembling the Dwyka Tillite of the Southern Karroo. This rock is composed of subangular quartz grains of sizes varying from fine to coarse, cemented with what looks like rock-flour. It contains scattered pebbles, up to five or six inches in diameter, the larger ones usually polished and flattened, and sometimes striated. Most of the pebbles are of quartz or quartzite. On Platkop

(Victoria Peak) boulders up to 18 inches in diameter have been found in the tillite.

Below and around Maclear's Beacon, the highest point of Table Mountain, the glacial beds also occur. Numerous fragments of chert and other erratics occur along the path of the northern edge of the mountain; and near the Beacon the tillite is easily distinguishable from the sandstones forming the main mass of the mountain by its unbedded nature and polygonal weathering. Several large scratched pebbles have been found in it, and are now in the South African Museum; whilst it is still possible to obtain striated pebbles in situ and to note the variability of the erratics. The Upper Shale Band has been denuded from this area and occurs nowhere in the Peninsula.

East of the longitude of Worcester no investigations of note have been made into the nature of the glacial band. It undoubtedly thins in that direction. Haughton and von Huene have considered a thin band of pebbles near the base of the Upper Shale Band in the Zwarteberg Pass (Prince Albert) as the most easterly outcrop known of the glacial beds. North and north-west of Port Elizabeth the Geological Survey has been unable to distinguish a definite Upper Shale Band horizon.

Intraformational Folding.

One of the most striking features in connection with the Cape glaciation is the intraformational folding intimately associated with the tillite. This has been described from several localities by Haughton, Krige and Krige; and recent further investigations have shown that it is a general accompaniment of the tillite wherever the latter is found. The folds are symmetrical and assymmetrical synclines and anticlines which extend down through a maximum thickness of 300 feet in the sandstones below the tillite. The axes of the folds in general run in a direction approximately north-south, whilst the steeper limbs of the assymmetrical folds are in the great majority of cases the eastern ones. In some cases (as in the Hottentots Hollands) the top of an anticline has been torn from its base and moved forwards (eastwards) for a few yards. Tillite fills many of the synclines and the "Hard Band" often lies directly on the denuded crests of anticlines. The folds diminish in intensity as they are traced downwards away from the crests of the anticlines.

It is evident that the folding of the rocks below the tillite is intimately connected with the glaciation of the area, and that it occurred in unconsolidated and unloaded sediments. It is concluded that the folding was actually caused by the passage of an ice-sheet moving in general from west to east, the folds being formed just in front of the contact-line between the ice and the underlying unconsolidated water-logged sediments. As the ice moved forwards it planed or plucked off the tops of the anticlines already

formed. On retreat of the ice, large amounts of glacial detritus were brought down by subglacial streams and deposited as the fluvio-glacial "Hard Band" and possibly, when the supply of pebbles had ceased, as the succeeding Upper Shales. Evidence is accumulating to show that glacial action was not confined to this one horizon in the Table Mountain Sandstone Formation. Intraformational folding has been observed both above the Upper Shale Band (Wellington Sneeuwkop) and in the main mass of the sandstone (E. side of Table Mountain) although not on so extensive a scale as that already described; and occasionally large pebbles are found in the main mass of the sandstone. For example, there was recently discovered at Glencairn, near the base of the T.M.S., a somewhat irregular-shaped rounded boulder of sandstone 8 inches in length; and on the slopes of Brandwacht, near Worcester, an exposure shewed a number of large irregular fragments of dark shale with sharp corners embedded in a fine-grained quartzitic sandstone.

14. A BRIEF REVIEW OF THE DWYKA GLACIATION OF SOUTH AFRICA.

BY

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(Kimberley).

Introduction.

The view that the Dwyka Conglomerate was of glacial origin was first put forward by SUTHERLAND in 1868. Confirmation came from DUNN & STOW some time later and considerable advances as well, particularly in respect to its distribution, while after them came SCHWARZ, ROGERS, MOLENGRAAFF, ANDERSON, MELLOR and others. The result of their combined labours has been to establish beyond question the existence during the late Palaeozoic of widespread glacial conditions over the southern end of the African Continent. It is true that several geologists have either doubted or denied its glacial origin, SANDBERG having maintained that it is volcanic, but the evidence for the prevailing view is too palpable to require defence, since practically every essential feature characterising existing glaciers and ice-sheets is to be found represented in this ancient formation.

While glacials of approximately similar age have been found to be quite as widespread in other parts of the Southern Hemisphere, the following outline will serve to disclose that probably more is known about the physiographical conditions and the history of the ice-movement in South Africa than in those other countries.

In 1922 the writer[1] gave a fairly comprehensive account of the state of knowledge concerning the Dwyka Series, and since that date the only further important contribution has been one by HAUGHTON & FROMMURZE on the two facies present to the north of Namaqualand. Under such circumstances it is not possible to add materially to the information already published, but, since the problem of former ice-ages is one of the subjects set for discussion by the International Geological Congress, the Dwyka Glaciation is briefly reconsidered in the following pages, rather, however,

[1]. A. L. DU TOIT. The Carboniferous Glaciation of South Africa. *Trans. Geol. Soc. S.A.*, xxiv, p. 188, 1922.

in a series of detached sections, than as a connected whole. No large areas remain unmapped in which the formation is either known or is suspected to occur, so that future advances in our knowledge would largely be made by way of more detailed work, particularly in regard to various questions that have only thrust themselves upon our notice during recent years, for example the detection of true interglacial periods.

Glacial Criteria.

Admirable descriptions of the tillite have been given by several writers, so that only the following summary need be submitted. All gradations are to be found from coarse boulder-beds through unstratified tillite — which composes the bulk of the rock met with — and angular gravel ("gravel-Dywka") to partly or wholly stratified boulder mudstones and shales with associated seasonally-banded "varve" shales and interglacial sandstones.

Quite a high proportion of the inclusions, which range from particles up to blocks several tons in weight, exhibit polishing, scoring, grooving, facetting or soleing, and can in certain cases be proved to have been transported for hundreds of miles. Pseudo-boulders of now-consolidated sandy and gritty material containing occasional pebbles are also to be found.

The floor upon which these varied materials rest may be flat, undulating or steep and sometimes vertical or rarely undercut; when hummocky, it may display fine "stoss" and "lee" sides. Where such have not been removed by erosion, they show striations that are parallel or cross at a small angle, and these may be attended by gouges, chatter-marks, facets and by "plucking" just as in the case of typical modern *roches moutonnées*, while an occasional "boulder-pavement" within the mass of the morainic matter gives testimony to the readvance of the ice. Only rarely has the till been thrust into joints in the floor, but weak strata, where over-ridden, have been shattered and the fragments incorporated in the boulder-bed.

Excavated rock-basins and also drumlins are not uncommon, while even an esker has been discovered; indeed about the only features not yet identified with certainty are terminal moraines marking stages of retreat, but that may be through want of careful observation. It should be noted in this connection that these phenomena have to be sought for within the usually restricted belts, that are exposed between the floor, now being eroded, and the covering of younger, post-glacial beds.

The more carefully that this remarkable formation is studied, the more apparent become the points of similarity or analogy with the products of living ice-fields, making allowance of course for induration and subse-

quent mineral changes. Despite SANDBERG'S[2] allegations, the phenomena are utterly unlike those distinguishing volcanic breccias or mud-flows, while, contrary to his assertions, the only materials of volcanic origin consist of the transported boulders and particles of extremely ancient lavas belonging to the Ventersdorp and Transvaal Systems. In the face of the above the author refuses to depart from his contention that there is naught to be gained in disproving SANDBERG'S views or in explaining the difficulties that he seems to have found, more particularly since those members of the Congress most competent to judge have after the examination of certain typical sections most definitely pronounced in favour of the accepted theory.

The Pre-Glacial Topography.

The lacustrine or estuarine "White Band," at the top of the Dwyka Series, forms a most valuable datum plane, that enables the absolute height of the land surface at the close of the glaciation to be computed with a fair amount of precision. The results are in accord with the conclusions obtained from the study of the extra-African tillites, namely that the land surface was on the whole one of relatively small relief, a deduction that effectively disposes of the idea, unfortunately still held by certain responsible persons, that the gathering grounds of the ice stood at a great altitude.

In those times South Africa was constituted by a peneplain of small height, from which rose certain blocks in the north-west, centre and north-east, the mountains of which could not, however, have ascended to more than a few thousands of feet above sea-level, even making due allowance for glacial erosion; the continent must indeed have been much lower than as at present. In the extreme west, in South-West Africa, the moraine was deposited in a shallow ocean, while in the south the ice-front seemingly passed into an extensive body of fresh or possibly brackish water, which followed up the ice-front during its retreat, and in this the Upper Dwyka Shales were laid down so far as the foot of the areas of higher ground referred to above.

The uneven character of the latter can most clearly be made out in certain parts of Natal and Zululand, where differences in level amounting to as much as 800 feet are to be observed within a distance of a mile or two, while in Griqualand West figures of at least 1,000 feet are indicated. That the ice crossed ridges and valleys without being appreciably deflected by them is another noteworthy feature, such as is well marked both along the Lower Vaal River and in Natal.

The overlap of the successive zones of the Karroo System upon the Transvaal "highlands" proves that much of that region was not buried

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[2]. C. G. S. SANDBERG. The Origin of the Dwyka Conglomerate of S. Africa. *Geol. Mag.* p. 117, 1928.

beneath sediments until well into the Triassic-portions, not even then. Through such lengthy exposure the ridges were stripped of much or all of their morainic covering, and the waste deposited over the "lowlands" in the form of fluviatile conglomerates, pebbly grits, etc., such as built up the Ecca Coal Measures. Furthermore the till that remained become somewhat weathered, and is now a pale rock in which some of the boulders may have suffered rotting, and the formation differs strongly from the fresh blue-green tillite of the lower-lying region to the west, south and south-east. The limit of this region of post-glacial weathering has not been closely defined, but lies more or less to the north-east of a line drawn from Lichtenburg through Klerksdorp and Kroonstad to Piet Retief. It is probably because of the intensity of such erosion that the tillite has not been recognised with certainty to the north of Mariental, Palapye, Messina or in the low-veld of the Eastern Transvaal, a subject which is referred to below.

Ice-Radiation.

Detailed evidence was presented in 1922 to show that the ice appeared to have radiated outwards from the blocks of higher ground as four bodies, namely, A. the Nama Ice, in South-West Africa; B. the minor mass of Griqualand West; C. the Transvaal body; and D. the Natal sheet with its centre situated out in what is now the Indian Ocean — perhaps part of the sheet that invaded Madagascar. The first of these moved southwards into the north-western corner of the Cape, scoring the rocks, but to the south of Seeheim the peculiar boulder-beds, flagstones and mudstones laid down appear to be more in the nature of outwash gravels than true ground moraine. The northern limit to the ice is unknown but the latter seems to have originated in the highlands around Windhoek. Haughton & Frommurze[3] have confirmed that, after the melting of this body, this area was overrun by the Transvaal and Griqualand West ice, moving in a west-south-westerly direction, bringing in boulders from several hundreds of miles, to the east, and covering up the till previously laid down by the Nama body. In turn the ocean followed up the easterly withdrawal of the second sheet, when the younger moraine became buried beneath muds carrying occasional small erratics, succeeded by shales with scanty fossil remains, such as *Eurydesma, Conularia, Orthoceras* and echinoid fragments, overlain by the carbonaceous pyritic shales of the uppermost Dwyka (White Band.)

The Transvaal sheet was undoubtedly the largest of the four, since at its maximum it extended south-eastwards into Natal, overwhelmed the

[3]. S. H. Haughton and H. F. Frommurze. The Karroo Beds of the Warmbad District. *Trans. Geol. Soc. S.A.*, p. 133, 192.

Griqualand West centre, reached beyond the southern edge of the Karroo and penetrated Calvinia and South-West Africa. This represents an area of about 900 miles in diameter. The enormous thickness of the morainic matter in the south, up to over 1,500 feet, points, first, to an extremely long life for the body and, secondly, to a wearing down of the gathering ground to the depth of several hundreds of feet at least. During its north-easterly and northerly retreat fresh or brackish water followed up the ice-front, and at least one readvance can be made out. Along the pre-glacial trough that is now occupied by the Harts-Vaal-Orange River, boulder-shales and mudstones and varve shales were deposited. Regarding the northern limit of this body some remarks will be made below.

The Natal Ice entering from the east-north-east came into conflict with the Transvaal mass, a careful study of the records written in the rocks enabling the struggle for mastery to be partially read. Conspicuous was the deflection of the invading body towards the south by the glaciers descending from the north-north-west, while oscillations of both bodies are indicated, more marked in the case of the Natal Ice. To the north of the line that demarcates the northern edge of the latter a yellow interglacial sandstone is developed well up in the northern tillite over an area of some hundreds of square miles, which is regarded as having been laid down by a river marginal to the southern ice-sheet. Several features collectively suggest that the Transvaal Ice was the first to disappear.

To sum up, the ice over each of the three main centres seems to have attained its maximum at a slightly different date, the overlapping of the resulting ground-moraines taking place in order from west to east. This easterly migration of the glacial centre is in accord with the deductions in the case of the Pleistocene Glaciation of North America, and is indeed such as could be anticipated on meteorological grounds.

Varve Shales.

Seasonally-banded shales have as yet been recorded from only a few localities, but their apparent scarcity can largely be put down to want of observation. Even in those observed the relative thicknesses of the successive laminae have not been studied and it is therefore not known whether any regular climatic cycle can be detected, such as has been deduced for the banded clays of the Pleistocene. At Nooitgedacht and Riverton Pan, near Kimberley, they follow directly upon the tillite and their regular stratification repeats in its curves and inclinations the drumlin-like forms of the underlying moraine that lies moulded over the *roches moutonnées*.

Because of the high alkali content found by Osborne[4] in varve shales from N.S. Wales, an analysis was made in the De Beers Laboratory of

[4]. T. W. E. David. Summary of Report of Glacial Phenomena Committee. *Rept. Austr. Assen Adv. Sci.*, xvii, p. 64, 1924.

material from Nooitgedacht. The figures, potash 2.09%, soda 2.15%, are however, no higher than those present in the average analysis of shale, save that in the Dwyka material the soda is in excess over the potash.

Some remarks made by COLEMAN[5] would indicate that certain laminated strata forming the very top of the Lower Dwyka Shales near Lainsburg may also be seasonal, but a few specimens belonging to that horizon at Grahamstown do not in their variation in grain-size conform with those of typical varve shales. An instructive problem is nevertheless presented for research.

Interglacial Periods.

While the author has already stated that oscillations of the ice-fronts are definitely indicated, not improbably to a considerable degree, COLEMAN believes that the available evidence would suggest more extended retreats and readvances, amounting in some cases perhaps to true interglacial periods. Bearing in mind, however, that the four centres came successively into action, the phenomena observed could quite adequately be explained as due to the overlapping of the moraines laid down by the several ice-sheets as they grew or shrank. It might indeed require much detailed work before it could be determined, whether during any phase the ice dwindled so extensively, that the climate became temperate for a period. To use a stratigraphical analogy South Africa has a series composed of glacial beds containing certain "breaks," the magnitude of which, as measured by both the time- and temperature-scale, it is impossible as yet to determine.

Directing attention on the other hand to the remaining southern continents, it becomes possible in certain localities to make such an evaluation, to measure the thickness of the strata equivalent to such a gap and to show by means of their contained fauna or flora that the conditions were decidedly not rigorous. For instance the main tillite of Southern Brazil is represented in Uruguay and again in Western Argentina by three boulder-beds parted by normal sediments, carrying plant remains in the latter area, while similar evidence can be quoted from South-eastern Australia and Tasmania. At Laingsburg and farther to the east on the Sundays River the Dwyka tillite contains one clear disconformity marked by a thin band of shales, while in Natal a double and sometimes a triple tillite is to be found, but in no instance is the magnitude of these intra-formational breaks to be measured directly. Indirectly, however, as will become apparent, when the age of the glacial beds is being considered, there is much in support of the view, that the retreat of the ice was in one or more instances not only considerable, but of long duration. It is therefore not unlikely that future work will demonstrate that one or more truly inter-

[5]. A. P. COLEMAN. *Ice Ages, Recent and Ancient*, p. 130, 1926.

glacial periods occurred in S. Africa in between the maxima of the Nama and Natal ice-sheets.

Northerly Limit of the Dwyka Ice.

It has long been appreciated that nowhere has evidence been found pointing to any equatorial movement of the ice-sheets. Unlike S. America and Australia the flow in S. Africa has everywhere been towards the South Pole. Coleman, in directing attention to this peculiarity, has drawn the obvious deduction, that the area within which the morainic matter is found was merely the southern part of the far larger region that was buried beneath the ice at its maximum, and that the equatorial limit to the ice-front lay far to the north of the Union.

In Southern and Northern Rhodesia and in Nyasaland the basal, often conglomeratic or brecciaform, beds of the Karroo System are seemingly of post-Dwyka age, and it remains uncertain whether the tillite was ever laid down in those parts, but removed by post-glacial erosion. In the absence of positive data the northern limit to be set to the ice becomes conjectural, though there are no valid grounds for denying that the cap might have covered Southern Rhodesia or country even farther to the north. The author has indeed pointed out that certain boulder-beds in the Eastern Congo suggested a glacial outlier, bearing the same relationship to the main cap in the south as that of the Alps to the Scandanavian mass during the Pleistocene. From this Sluys[6] has dissented on the score that the Congo glacials would indicate a body of continental dimensions, but the most recent pronouncements confer a probably pre-Palaeozoic age on the tilted and folded glacials of Katanga and the Lower Congo. Furthermore, of those recorded by Ball, Shaler, Passau and Fourmarier[7] at the base of the nearly horizontal Karroo Beds farther down the Lualaba River and its eastern tributaries, the palaeontological evidence is insufficient to allot them to any particular stage of the system, and they may, as has indeed been claimed, possibly be as young as Triassic. It is nevertheless instructive to note that the direction of ice movement in the Eastern Congo appears to have been northwards generally.

The problem must, therefore, await investigation of the little known territory to the north of the Transvaal border and in the Kaokoveld of South West Africa.

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6. M. Sluys. Les Périodes glaciaries dans le Bassin Congolais, *Comp. Rend. l'Assoc. Franc. l'Avanc.* Sci., p. 675, 1923.

7. P. Fourmarier. Le Bassin charbonnier de la Lukuga. *Ann. Soc. Géol. Belg.; Publ. rel. Congo. Belge.*, p. 77, 1916.

Age of the Glacials.

It will be instructive to summarize our knowledge on this question in view of the opinion so frequently expressed for an early Permian date, and more particularly of the very definite pronouncement by that eminent palaeontologist SCHUCHERT, for a Middle Permian age. In considering this problem it becomes necessary to review the evidence from the other sections of Gondwanaland as well as that from S. Africa. Most peculiarly, in dealing with this question so many persons seem to have confined their studies to the alliances of the fossils found *above* the tillite, but to have ignored the more vital palaeontological evidence obtainable from the basal portions of these glacials. It is largely because of this omission, that a Permian or Permo-Carboniferous age has so widely been advocated.

In San Juan, Argentina,[8] three tillites are present at the base of the Gondwana (Paganzo) System, the basal one of which rests unconformably upon a striated surface of Lower Palaeozoics and is followed directly by shales with a *Cardiopteris-Rhacopteris* Flora. Not far distant is a tillite, regarded as its equivalent, succeeded by strata with a marine Uralian fauna. The glaciation is hence proved in each case to have commenced not later than the beginning of the Upper Carboniferous, and quite probably, as indicated by the plants, before the close of the Lower Carboniferous. In Uruguay three boulder-beds occur in corresponding position at the base of the Gondwana (Santa Catherine) System, but in Southern Brazil only one glacial group is known (Itararé), though suggestively in Paraná and Sao Paula it is compound. In the Sierra de la Ventana, Argentina, the thick tillite succession is also a multiple body with one important sedimentary intercalation at least. Both in Uruguay and the three localities in Argentina the direction of ice-movement was the same, — north-westwards — and there is no reason for doubting the general equivalence of the glacial series in the several areas. Clearly then, farther away from the centre of glaciation the intercalations, that mark out major retreats of the ice, become thicker.

Now the geological evidence indicates most unmistakably the full equivalence of the Sierra de la Ventana tillite with that of the Dwyka, and in the latter the compound body of the Southern Karroo is represented around the Transvaal centre by a single tillite. It is highly probable that the very lowest portion of the southern Dwyka boulder-bed corresponds almost exactly with the basal tillite of San Juan, a view greatly strengthened by its perfect conformity through the medium of the Lower Dwyka Shales with the Witteberg Series, which is of Devono-Lower Carboniferous age.

8. A. L. DU TOIT. A Geological Comparison of S. America with S. Africa. *Carnegie Inst.* Publ. 381, p. 28, 1927.

Proceeding to Australia we find near Seaham and Paterson a remarkably close resemblance with Western Argentina, in that a group of fluvioglacials and glacials with a *Cardiopteris-Rhacopteris* flora rests unconformably upon older Carboniferous strata and has at one point a striated floor. This Kuttung Series is ascribable to the uppermost part of the Lower Carboniferous (the Middle Carboniferous of some writers), while above it comes the Lower Marine Series with a fauna of "southern" type and also *Gangamopteris* and *Eurydesma*, as so ably set forth by Süssmilch & David.[9] The Lower Marine Series and the Lower Bowen Series of Queensland, including the *Eurydesma* beds, are regarded by Whitehouse as of Upper Carboniferous age, as indicated by the evolution of the cephalopods. Parallelling them is a multiple series of boulder-beds in Tasmania with interbedded conglomerates, etc., while boulder-pavements testify to several readvances of the ice. The sequence in Victoria is similar, but mainly terrestial. In Western Australia the widespread tillites of the Irwin, Gascoigne and Kimberley areas are overlain by strata with Uralian fossils showing a distinct Indian facies, important being the presence of *Paralegoceras (Gastrioceras) jacksoni*.

It is hence clear that the lengthy refrigeration of the Southern Hemisphere started just *before* the close of the Lower Carboniferous and that the main phases terminated before the end of the Upper Carboniferous. The evidence has been well reviewed by David, but one point might be enlarged upon with profit. A valuable datum is afforded by that rare genus *Eurydesma*, which is known from four localities, South-west Africa, New South Wales, Queensland and Salt Range, India, in each case above the glacials. In the last-mentioned spot it is followed by strata with the normal Tethys marine fauna, namely by the Productus Limestones. It is almost entirely from this particular sequence in the Salt Range that Schuchert[10] has built up his arguments for the Middle Permian age of the main Gondwana glaciation, and the evidence hence demands a careful scrutiny. Remarkably straightaway is the fact, pointed out by Schuchert himself, that the Eurydesma fauna has nothing in common with that of the overlying strata, none of the species within it passing up into the Lower Productus Limestones, a fact which indeed suggests an hiatus. His contention that the Lower Limestones are not older than lowest Upper Permian finds definite opposition in the writings of other palaeontologists, and they can be taken as not younger than Lower Permian and not improbably late

[9]. C. A. Süssmilch and T. W. E. David. Sequence, Glaciation and Correlation of the Carboniferous Rocks of the Hunter River District, N.S.W. *Proc. Roy. Soc. N.S.W.*, liii, p. 246, 1920.

[10]. C. Schuchert. Review of the Late Palaeozoic Formations and Faunas, etc. *Bull. Geol. Soc. Amer.* 39, p. 838, 1929.

Uralian, as so clearly set forth by H. DIGHTON THOMAS in a review that has only just made its appearance.[11].

It follows, therefore, that the ice must have melted away before the beginning of the Permian in India, N.S. Wales and South-West Africa. In the latter region it was the Transvaal sheet that was succeeded by the sediments containing *Eurydesma*. But that body on the other hand invaded the area only *after* the disappearance of the Nama Ice, which must have been much older — probably contemporaneous with the lowest of the sheets that operated in Argentina and New South Wales.

To sum up, it can be said that the several glacial phases in S. Africa, together constituting the "Dwyka Glaciation," began with much probability at the end of the Lower, and terminated not later than the close of the Upper Carboniferous. In the other parts of Gondwanaland a similar antiquity is indicated, covering practically the same lengthy span of geological time. In a paper that is being presented to this Congress the author is drawing attention to the fact that the palæo-botanical evidence points strongly in the same direction, while in a second contribution HAUGHTON is reaching a like conclusion based on the evolutionary history of the Karroo reptilia.

The Bearings of the Displacement Hypothesis.

It is well worth discussing this illuminating hypothesis, since recent advances in our knowledge appear to be favouring more and more its probability. In doing so it must be explained that the author, while advocating a condensed "Gondwanaland," finds it impossible to agree with WEGENER'S views as regards the position allotted to the poles during their wanderings through the geological epochs, the consequences of which have been criticised by BROOKS.[12]

The particular restoration, given in sketch-form in 1922 and still favoured, is one in which the present coast lines of the several portions of the Southern Continent are not brought into apposition, full allowance being made for the width of the continental shelves, marginal stretching of the sial and subsequent erosion, but account is not taken of any distortion of the masses, though such must have been considerable in certain zones. Certain features point to a lesser distance between Tasmania and Patagonia, but, until further exploration has determined the limits of Antarctica or of its hypothetical portions, this part of the restoration must remain purely tentative.

Gondwanaland then presents itself as a bilobate mass with a long offshoot from the early "Tethys" ocean penetrating between India and

[11]. H. D. THOMAS. The Late Palaeozoic Glaciation, *Nature*, cxxiii, p. 946; 1929.
[12]. C. E. P. BROOKS. *Climate through the Ages*. Ch. xiii, 1926.

Western Australia, past the south of the Cape until opposite S.W. Africa. The probability of such an extensive gulf is strongly indicated by the great development on the north-western and western edge of Australia of glacials with associated strata having marine fossils showing Indian affinities, the presence of marine Carboniferous in Southern Madagascar and the Eurydesma fauna in S.W. Africa.

The areas known to have been glaciated would flank this gulf and occupy two tongues, the one extending from India through Madagascar, S. Africa, Brazil and Uruguay to Argentina, the other stretching from the heart of Australia to S. America or else forming an independent body. Such a gulf, fed with warm water from the equatorial stream, could have provided the necessary evaporation for the maintenance of ice-caps upon the adjoining, but relatively low-lying lands. This would partly meet COLEMAN's objections that the areas occupied by ice under this hypothesis were so extensive, that the snow-fields could not properly be fed, though it should not be overlooked that proximity of the ice-sheets to the oceans is clearly indicated by marine boulder-beds at many places along the borders of the areas known to have been glaciated, for example in Western Argentina, Brazil, S.W. Africa, Salt Range, Western Australia, N.S. Wales and Tasmania.

We have furthermore evidence that in S. Africa the several ice-centres attained their maxima at different dates, and a similar migrational-sequence might have characterised the rest of the Southern Continent, like that deduced for the Pleistocene glaciation of N. America. It was indeed only to the north of the Argentine-African ice-body and that of Australia that the ice-free territory attained to any really considerable width; the state of Antarctica at that period is unfortunately unknown.

While the total area beneath ice was truly enormous, the evidence does not lend support to the view that the whole of it was covered at any one instant, not even during the maximum phase of glaciation. The presence of overlapping fields in S. Africa indeed suggests a number of more or less independent centres, which did not quite synchronise in their development, culmination or waning, just as was the case during the Pleistocene in the Northern Hemisphere.

Ignoring for the moment the weighty geological evidence in support of the displacement hypothesis, it can scarcely be denied that such a geographical restoration has much in its favour, since it brings into close association a number of continental blocks upon which a series of similar and correlated geological events and climatic episodes progressed in orderly fashion during the Carboniferous. It can furthermore be claimed that the mechanisms to be invoked for explaining the observed glaciations under such an hypotheiss are not more elaborate than those that have to be conjured up to account for the array of disjointed, though more or less synchronous refrigerations in land masses fixed in latitudes that lie some-

times within the tropics, for instance the Kimberley district of Western Australia or Peninsular India. It can, moreover, be noted that the Carboniferous South Pole need not be assumed to have lain at the centre of such a continent. Even if it be presumed to have been situated in Antarctica or on the borders of that continent, all the areas known to have been glaciated could still be made to fall between 45 and 90 degrees of latitude and hence well away from the Carboniferous Equator, thus paralleling very closely the conditions represented in the Northern Hemisphere during the Pleistocene. Just like the latter an eccentric position as regards the pole could well have been the case in the late Palaeozoic, the author having pointed out the meteorological consequences thereof.[18]

Many theories have been propounded regarding the cause of the Carboniferous Glaciation. The meteorological aspect has been well discussed by Köppen and Wegener and by Brooks, but it seems to the writer that before meteorological principles can properly be applied, it will be necessary to obtain a more definite picture of the distribution of land and sea and of the position of the South Pole in relation to the several continental masses. It can hardly be disputed that such arguments based upon the orthodox concept of Gondwanaland could not be applied to any system of distribution consequential upon the displacement hypothesis. It is for this reason that attention has been directed to the latter and particularly to one special form thereof.

SUMMARY.

1. The Dwyka boulder-beds are typical, compacted, glacial deposits, quite unlike volcanic breccias or ash-beds.

2. They rest generally with unconformity upon polished and striated floors, often of *roche moutonnée type*.

3. During their formation the land was mainly low-lying, but had three mountainous blocks rising towards the north, that served as gathering grounds for snow and ice.

4. The ice-sheets radiated from three main and from one minor centre, giving rise to the Nama, Griqualand West, Transvaal and Natal bodies, of which the oldest lay in the west, the youngest in the east.

5. The Transvaal highland suffered extensive erosion in post-glacial times and much of it was not buried beneath Karroo sediments until a later epoch.

6. Seasonally-banded "varve" shales occur rarely.

7. Advances and retreats of the ice are indicated by breaks in the mass of tillite and by boulder-pavements, though the evidence is insufficient to decide the former existence of true interglacial periods. Comparison with other parts of Gondwanaland having a similar history suggests, however, that such was the case in S Africa also.

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18. A. L. du Toit. *Loc cit.*, p. 222

8. Only a general poleward movement of the ice can be made out; the presumed northern side of the cap or caps has not been found and its limit equatorwards is problematical.

9. Determination of the age of the Dwyka has to be made indirectly. In Argentina and N.S. Wales the *Rhacopteris-Cardiopteris* flora in the basal part of the glacials proves a late Lower Carboniferous date, while the base of the equivalent Dwyka tillite is in the south conformable with the Devono-Lower Carboniferous Witteberg Series. The superior limit is fixed by the overlying strata in S.W. Africa, India and E. Australia with *Eurydesma,* and in Argentina and W. Australia with marine fossils of Upper Carboniferous (Uralian) affinities.

10. The Continental Displacement Hypothesis, with a bilobate Gondwanaland situated in the Southern Hemisphere, is strongly favoured by geological evidence under it the areas known to have been placiated are brought closely together and their very similar histories find a readier explanation than under orthodox views.

11. Until the Carboniferous geography can be restored with reasonable probability, a meteorological explanation of the cause of this great refrigeration is impossible.

14A. GLACIAL DEPOSITS — TILLITES — OF THE LOWER CAMBRIAN AGE IN THE YENISEI RIDGE.

BY

J. NICOLAEV.

On a reconnaissance in the north-west of the Yenisseisk district in 1927 I met with peculiar conglomeratic deposits which in the field were ascribed to glacial agency. The unfavourable conditions prevailing in late autumn, when the work in the region (the upper valley of the Vorogovka River) where these rocks reach their fullest development was done, prevented me from giving them as much attention as their interest warranted.

In 1928, however, when carrying out a reconnaissance near the Vorogovka River, I revisited the upper valley in order to complete my earlier observations on the ancient glacial deposits, and succeeded in collecting additional material, such as striated boulders, and in securing photographs of some of the structural details. My collections, however, are not exhaustive, for the upper valley of the Vorogovka River (in lat. 61°N. and long. 91° — 92°E.) is a desert difficult of access and almost unexplored.

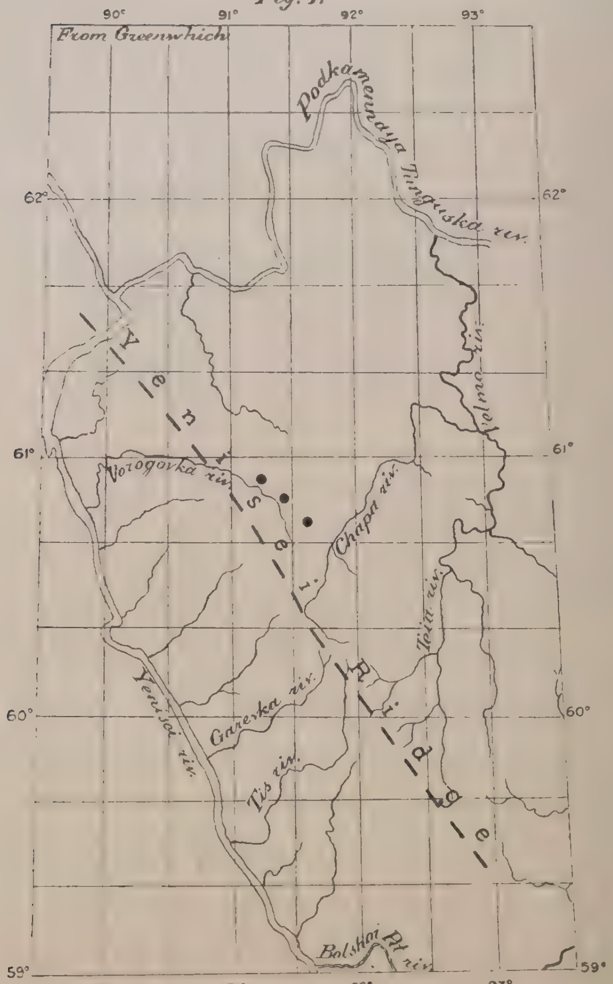
Before describing the ancient glacial deposits of the Yenisei ridge, it is advisable to give a short account of the geological structure of the ridge itself, based upon previous work and my own observations.

In considering the structure of the Yenisei ridge two elements must be distinguished, which, owing to their lithological characters and age, may be easily done throughout the area; they are the complex of crystalline schists, and the normal sedimentary rocks assigned to the early palaeozoic.

The first group is represented in our area by a series of injected rocks, gneiss and migmatites, by various crystalline schists, marbles, amphibolites and phyllites, with layers of cherty limestone and dolomites. To the north-west, outside the limits of the map, in the region of the Katookasa, Isakova and Surnikhi, tributaries on the right bank of the Yenisei, green schists derived from basic intrusive and volcanic rocks (including tuffs) assume equal importance in the structure of the ridge. Correlation of the several members of this crystalline series is in general very difficult owing to their metamorphism and subsequent dislocation. Yet in spite of its complexity one can distinguish in this great mass of rocks, mainly of sedimentary origin, two distinct groups separated by a break.

SKETCH MAP
OF THE
N. E. PORTION OF THE
YENISEI RIDGE

Fig. 1.



• *Tillites.*

The second great group of rocks in the Yenisei ridge consists of a series of normal sedimentary rocks, the so-called "Red Beds," whose central portion is usually made up of bands and wedges of various dimensions limited by dislocations. It is only at the periphery of the ridge that a fairly complete section through these rocks appears.

The Cambrian age of the sediments may even now be admitted, though it is based on incomplete information and general consideration of the sedimentary rocks of the region; and it is possible to divide the rocks into

To face page 105.

1. Communication No. 14A.

1. General character of the tillite outcrops of Vorogovka river, Yenisei Ridge.

(For scale see pocket knife).

2. Communication No. 14A.

2. Polished granite boulder enclosed in the tillites of the Vorogovka river, Yenisei Ridge.

groups by their lithological characters. My observations led to the following classification in upward succession:—

1. Dark grey calcareous shales with layers of dolomite, green grauwackes with interbedded thin and dark argillaceous shales (platy shales). At the base of these deposits is a great thickness of tillite, and in the section seen along the Chapa River the thickness of the beds above the glacial deposits ranges up to 300 m.
2. Reddish, brown and grey arkose with sandstones made entirely of quartz, at places conglomeratic. These beds range up to 1200 m. in thickness (Cm_1).
3. Dull grey shales with undulating lamination, pink and light green marls passing into white, dolomitic, porous and brecciated limestones sometimes raddled and, in the upper layers, thinly laminated and dolomitized. The thickness seen is not under 500 m. (Cm^2).
4. Red calcareous conglomerates, sandstones, shales and variegated marls, up to 200 m. thick. (Com_3 ?).

North and north-west of the Yenisei ridge the Cambrian beds are capped by Silurian, which contain a rich fauna on the Stony Tunguska, allowing its division into two groups.

As stated above, the supposed glacial beds are seen in their most typical form in the upper part of the Vorogovka valley; with gaps due to tectonic disturbance which brings these beds into contact with higher palaeozoic rocks, the formation may be followed down the river for about 30 Km. The formation was again seen by the author between the Vorogovka and Chapa Rivers, near a spring flowing into a left-bank tributary of the latter, the Suktalma Creek.

A general feature of these sediments on the banks of the Vorogovka is the absence of bedding; the great group of conglomeratic deposits is compact, fine-grained, sandy and calcareous, with scattered angular or slightly rounded fragments of diverse rocks; these fragments are of various sizes, even exceeding a meter in diameter (photos 1 and 2). The colour of the deposits varies from greenish and brownish gray to the dark grey characteristic of the highly calcareous varieties which commonly have a film of graphite on the slickensides; the deposits are also found to be reddish in colour, clearly owing to the infiltration of oxides of iron.

For such sediments the term "till" (boulder clay) has been proposed, and in the hardened state they are called tillites, a term accepted by Grabau (Principles of Stratigraphy, p. 534). In spite of the uniform lithological character of the tillites on the Vorogovka River, certain varieties may be distinguished owing to the predominance of large boulders in some outcrops and the presence of small angular fragments only in others. In most of the outcrops the cleavage varies in degree, and only rarely is the tillite entirely without cleavage planes. The inclusions may be cut by the more marked planes of shear, and they may be oriented in relation to

the pressure which produced the cleavage, the long axis of an inclusion lying along the cleavage and being slightly compressed and drawn out in the same direction; in such cases the fragments may assume a lenticular form. Thus the Vorogovka tillites are altered rocks: at places they are veined by quartz with drusy form, and calcite has impregnated the mass of the rock. The tillites are so hard in the outcrops that it is very difficult to break off a hand-specimen or an inclusion; they also offer much resistance to weathering, as is proved by the character of the outcrops. The deformed inclusions are more easily weathered, especially the limestones, some of which are represented by cavities partly filled with ochre.

Since the tillites are lacking in planes of bedding, one has to estimate their dip by observing the occasional instances of their passage into distinctly laminated sandstones, which have been noted in two places only.

The anticlinal disposition of the whole group can be deduced from the lie of sandstone beds, e.g. the south-west limb of an anticline is revealed on the Vorogovka, where the tillite appears in the arch. Under such conditions the thickness of the tillite may be determined approximately, and the author finds it to be not less than 800 m. in the part seen. In the Vorogovka sections also the unconformity of the tillite lying on the Pre-Cambrian cherty limestones, phyllites and quartzites is well seen. These outcrops show the tillite lying on the uneven surface of the metamorphic rocks, and the dark grey cherty limestones which form thick belts in the phyllite complex appear as considerable ridges capped by phyllites (photo No. 3); the rocks underlying the tillite are much disturbed.

The later date of the tillite is abundantly proved by the presence in it of fragments of the metamorphic rocks.

Another piece of evidence, illustrated by photo No. 4, helps to determine the stratigraphical position of the tillite. The outcrop consists of schistose tillite at the base covered by thinly bedded, light green dolomitic limestone which can be identified as part of the Upper Middle Cambrian. In my opinion the unconformity at the base of the limestone is the result of marine transgression in lower palaeozoic times over the continental glacial beds.

The well developed cleavage in the tillite may appear to contradict the view expressed above that the tillite is part of the older palaeozoic formations, for the latter are in general characterized by the relatively moderate degree of structural alteration they exhibit. The contrast is, however, explained by the greater sensitiveness of the essentially argillaceous tillite to tectomic forces. The erratic blocks in the tillite come from the metamorphic complex. We have found boulders of dark grey cherty limestones, grey quartzite, phyllites, light green calcareous schists characteristic of the Jenashimiski series, and also granites. The immediate superposition of the tillite on the metamorphic rocks has been described and makes the

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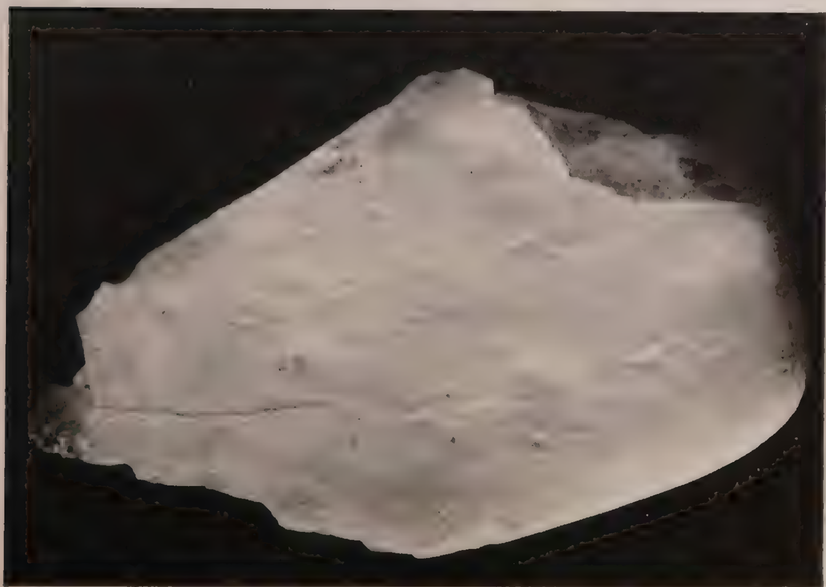
3 Communication No. 14A.



5. Communication No. 14A.

3. Uncomformable bedding of tillites on Pre-Cambriam rocks. The centre is a prominence consisting of flinty Pre-Cambrian limestones Vorogovka River, Yenisei Ridge

5. Surface of an erratic block from the tillite, with lines of glacial striae Dim. x2.5 Vorogovka River, Yenisei Ridge

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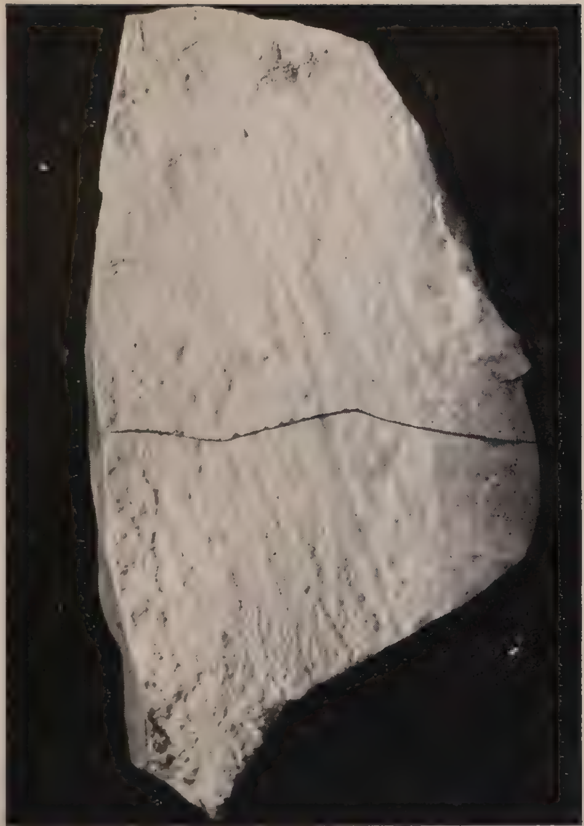

6.

6. Surface of an erratic block from the tillite with signs of glacial striations. Dim. x 2.5. Vorogovka River, Yenesei Ridge.

4.

4. Transgressive bedding of Middle Cambrian dolomitised limestones reposing on tillites. Vorogovka River, Yenesei Ridge.

origin of such boulders obvious. The transport of the granite boulders from a distance may be admitted; granite crops out at a distance of not less than 15—20 Km. to the south-east, south and south-west of the Vorogovka River, and the boulders were apparently transported by glacier ice.

In spite of the great development of boulder material in the tillite, distinct traces of glacial striae on the boulders are not often seen. I gave much time and attention to the search for striated boulders (see photos 5 and 6). The difficulty of transport only allowed me to bring away specimens which bore very clear evidence of glacial action, and I was obliged to limit myself to pieces broken from typical boulders showing glacial striae. In many instances boulders with distinctly polished surfaces are met with, but one could not bring them away for closer study because they could not be detached from the tillite matrix. The relative scarcity of boulders with glacial striae may be explained in part by the fact that the tillite has been subjected to earth-movements which obliterated the striae.

Glacial striations have not been seen on the floor under the tillite, but the surfaces available for study were of insignificant extent. The question of the direction of movement of the ice could therefore be surmised only on the supposition that the highest part of the Yenisei ridge of Pre-Cambrian rocks lay to the south-east, south and south-west of the Vorogovka.

It must be noted that many interesting details bearing upon the glacial origin of the peculiar rock in the Vorogovka valley are not illustrated in the material collected. This is easily understood when one remembers that even in regions where the conditions of study are more favourable than in the Vorogovka valley authenticity of the evidence of glacial action was decided only after long study and repeated visits. As regards the formations we are concerned with, their glacial origin is in my opinion proved by the peculiarities of structure and composition as well as by the discovery of boulders with unmistakable glacial striae.

The discovery of glacial beds in the lower Cambrian of the Vorogovka valley was not improbable from a geological point of view, for similar formations of that age have been observed on a large scale in other parts of the world, and V. Obruchev has admitted the possibility of their occurrence in Siberia.

The Dwyka conglomerate of South Africa and the corresponding rocks of southern Australia have been visited by well known geologists; they were long under discussion and their glacial origin is now established. In this connection we must call attention to the important paper by W. Howchin, in which there is a full description of the lower Cambrian glacial deposits near Adelaide in South Australia. The lower Cambrian age of the beds is proved by the presence of middle Cambrian limestones.

SECTION II.

THE KARROO SYSTEM;
its Stratigraphy, Palaeontology and World. Distribution.

15. BEITRÄGE ZUR FAUNA UND FLORA DER KARRUFORMATION SÜDWESTAFRIKAS.

VON

DR. PAUL RANGE.
Geheimer Bergrat in Berlin.

Die Kenntnis der Verbreitung, der Lagerungsverhältnisse, der Stratigraphie und Paläontologie der Karruformation Südwestafrikas hat in den letzten 10 Jahren grosse Fortschritte gemacht. Wir können sie jetzt den besser bekannten Horizonten der Union aus stratigraphischen und paläontologischen Gründen gleichstellen. Die wichtigste Besonderheit dieses Teiles des Subcontinents zur Karruzeit ist das Übergreifen des Oceans, nachdem das grosse Inlandeis des mittleren Namalandes geschmolzen war. Ein weiterer Unterschied zwischen dem Westen und den centralen Teilen der Union besteht in dem Fehlen der Beaufort Schichten. In dieser Zeit war der hochgelegene Westen vermutlich Erosionsgebiet. Am Ende dieser langen Kontinentalzeit Südafrikas werden die Ablagerungen wieder gleichartiger. Im nördlichen Teile des Landes, im Kaokofeld und Hereroland finden sich Sandsteine und Schiefertone der Stormbergschichten überdeckt von mächtigen Eruptivdecken; eine solche liegt auch noch bei Mariental under dem 24 südl. Beite. In nachstehender Tabelle gebe ich eine kurze Übersicht der Entwickelung der Karruformation Südwestafrikas nach dem jetzigen Stande unserer Kenntnis.

Namaland.		Hereroland *)		Südafrika.
Mandelstein decke von Kub und Hochanas rote Schiefertone.		Diabase und Porphyrite, rote und hellfarbige glimmerreiche Sandsteine mit Saurierspuren (Etjosandstein)		Stormberg Series.
Gansberg Konglomerat.				Beaufort Series?
Sandsteine und Schiefertone mit Landpflanzen.		Schieferton und Sandstein, Tuffe mit Mesosaurus und Pflanzenresten.		Ecca Series.
Graukuppe Schiefer, Eurydesma schichten, Tillit und fluvioglaciale Schichten.	Diabase	Grobe Conglomerate und Breccien nicht glacialen Alters.	Diabase	Dwyka Series.

*) Verschiedentlich sind in der Formationstabelle meines Aufsatzes "Rechts und links der Eisenbahn in Südwestafrika." Zeit. prakt. Geologie 1929. Heft 6. die liegenden Karruschichten des Hererolandes dem Beaufort Series parallelisiert.

Um nicht zu viel Raum zu beanspruchen folgen 2 Listen der bisher in dieser Formation gefundenen Tier-und Pflanzenreste:

Flora.	Nama-land.	Herero-land.	Fauna.	Nama-land.	Herero-land.
Artisia?	x		Tissoa siphonalis?	x	
Cyclodendron Leslei	x		Eurydesma cf. globosum.	x	
			Myalina	x	
Tylodendron?	x		Gastropoda	x	
Medullopitys sclerotica	x		Conularia sp.		
			Orthoceras sp.?	x	
Abietopitys perforata	x		Archaeocidaris	x	
Phyllocladopitys Capensis	x		Crustacea	x	
Dadoxylon purosum	x		Acrolepis Lotzi	x	
Rangei	x		Namaichthys Schroederi	x	
Arberi		x	Radinichthys	x	
Taxopitys africana		x	Elonichthys	x	
Schizoneura sp.	x		Mesosaurus tenuidens	x	x
Filices	x	x	Saurichnium damarense		x
			parallelum		x
			anserinum		x
			tetractis		x
			Tetrapodium Elmenhorsti		x
			Archaeotherium Reuningi		x

Einige Erläuterungen mögen zu diesen Verzeichnissen am Platze sein. Das Leben des Südwestafrika bespülenden Karrumeeres war nicht so arm als man früher annahm. Die ersten Funde von *Palaeoniscus, Conularia* und *Eurydesma* wurden von Schröder in dem Aufsatz: "Marine Fossilien in Verbindung mit permischem Glacialconglomerat in DSW. Afrika," 1908 beschrieben. Diese Fossilien waren nahe Ganikobis westlich der Eisenbahn Keetmanshoop — Windhuk unweit des Fischflusses gesammelt. Später fand Dr. Lotz Eurydesmen in grosser Menge bei Itsavisis und ich selbst konnte weiter Fundpunkte bei Gaus südöstlich Gibeon hinzufügen. Durch Maack erfuhr ich, dass er einen Gastropodensteinkern von etwa 10 cm Länge an dem Steilabfall an der Affenquelle östlich Mariental gefunden hat. Unglücklicherweise ist das Exemplar in der Kriegszeit verloren gegangen, so dass ich hier nur eine Photographie geben kann. 1927 vervollständigten Haughton und Frommurze unsere Kenntnis von der Meeresfauna der Karruformation durch die Arbeit: "The Karroobeds of the Warmbad District, South West Africa," sie machten ausserdem eine *Archaeocidaris* von der Haltestelle Brukaros namhaft. Somit können wir sagen, dass zur Dwykazeit — im Obercarbon — in einem seichten, wol mässig warmen Meere eine artenreiche

marine Fauna lebte. Dieses Meer erstreckte sich westlich des 18° östl. Länge von Greenwich über ein Gebiet von mindestens 400 km. Breite. Nehmen wir die höchstwahrscheinlich gleichalten Beobachtungen von Reuning am Doroskrater im südlichen Kaokofeld hinzu, so erhalten wir sogar 800 km. Küstenlänge.

Die Flora der Karruschichten Südwestafrikas ist weniger gut bekannt und wol auch nicht so reich wie die der Union. Zum Teil mag das an unserer mangelnden Kenntnis liegen, sicher sind aber auch die Gesteine in Südwestafrika der Erhaltung von Pflanzenresten weniger günstig. Bisher sind Kohlenflöze von irgentwie bedeutsamer Mächtigkeit im Namaland nicht beobachtet, hier liegt aber das weitaus grösste Areal von Karruformation. Nur ganz schwache Schmitzen von 1—2 cm Mächtigkeit sind am Weissrand östlich Gibeon bekannt. Im Bohrloch Witboyvley 70 km. östlich Gibeon wurden in 100—140 m. Spuren von Tourbanit bemerkt. Bei Gariganis südöstlich Keetmanshoop wurde in einem Schachtbrunnen ein schwaches Flötz verkokter Kohle gefunden, das durch Kontaktwirkung mit einem Diabasgang diese Beschaffenheit erhalten hatte. Alle zur deutschen Zeit gestossenen Bohrungen auf artesisches Wasser in der Kalahari östlich Gibeon sind von mir auf Pflanzenreste geprüft, jedoch ohne Resultat, es fand sich lediglich unbestimmbarer Pflanzenhäcksel. Daher stammt unsere Kenntnis lediglich von den Baumstämmen, die sich in weiter Verbreitung in den Karruschichten ganz Südwestafrikas finden, sie wurden von Kräusel genau untersucht und bestimmt. Auch in den Karruschichten des Kaofeldes fanden sich die gleichen Stammstücke, so dass auch diese den Ecca-Series entsprechen. Die wahrscheinlich zu den Stormberg Series gehörigen jungen Sandsteine haben ausser *Taxopitys africana*, die möglicherweise in diesen Horizont gehört, keine Pflanzenreste geliefert. Dass aber zu dieser Zeit reiches organisches Leben vorhanden war, beweisen die Tierfährten, welche Gürrich beschrieben hat und der zu *Archaeotherium Reuningi* gehörige Säugetierzahn, den von Huene bekannt machte. Aus der älteren Karruzeit sind bisher nur Mesosaurier bestimmt, die von Huene zu *Mesosaurus tenuidens* stellt. Die wichtigste Hölzer sind die Gymnospermen *Dadoxylon Rangei* und *Phyllocladoxylon capense*. Sie sind gut charakterisierte Arten, welche Jahresringe zeigen. Diese beiden Arten und *Cyclodendron Leslei* machen es sicher, dass die Horizonte, in denen sie auftreten, zu den Ecca-Series gehören. *Dadoxylon Arberi* scheint dagegen ein Sammeltypus zu sein, der keinen Artwert hat und deshalb zur Horizontierung nicht verwendbar ist. Die meisten Stämme sind Mesoxyloideen, die den Cordaiten nahestehen. Bisher waren solche nur aus der nördlichen Hemisphaere bekannt. Kräusels Untersuchungen haben ergeben, dass sie auch auf der Südhalbkugel vertreten sind.

So zeigt die Karruzeit Südwestafrikas folgendes Bild. Nachdem das Land mindestens zweimal von Inlandeis überzogen war, dessen Nährgebiet

einmal in der Mitte des Landes und das andere Mal östlich davon gelegen hat, überflutete von Westen her das Karrumeer dasselbe. Im Norden des Landes fanden zum Teil submarine Eruptionen statt, die ein Massensterben von Mesosauriern verursachten. Dann zog sich die Meeresflut zurück und Nadelhölzer wuchsen in dem Gebiet, das ein durch Jahreszeiten wol charakterisiertes Klima van mässiger Wärme hatte. Allmählich wurde das Klima trockener, das Land wurde abgetragen zur Beaufortzeit, während dauernd Eruptionen von Karrudiabasen stattfanden. Erst im letzten Abschnitt der Karruzeit fand auch hier wieder Sedimentation statt, welche Fusspuren von Sauriern enthält und eine starke Weiterentwickelung tierischen Lebens ahnen lässt, dem schon die ersten Säugetiere angehörten.

SCHRIFTENVERZEICHNIS.

Die ältere Literatur findet man vollständig bei Krenkel: Geologie Afrikas, II. Teil, Berlin 1928 auf S. 961-967.

Seitdem sind hinzugekommen:

A. du Toit: The Geology of South Africa. Edinburg. 1926. Gibt auf S. 257-261 einen ausgezeichneten Überblick über die Karruformation SW. Afrikas.

S. H. Haughton and H. F. Frommurze.. The Karroobeds of the Warmbad District SW. Africa. Transactions Geol. Society of South Africa, 1927.

R. Kräusel und P. Range: Beiträge zur Kenntnis der Karruformation Deutsch-Südwest-Afrikas. Berlin. Geol. Landesanstalt, 1928.

ABBILDUNGEN.

1. Eurydesma cf. globosum.
2. Gastropodensteinkern.

Beide aus den Eurydesmaschiefern der Dwykaschichten von Gaus und Mariental, Bez. Gibeon. S.W. Afrika.

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Fig. 1

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Fig. 2.

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Fig. 1. Eurydesma cf. globosum.

Fig. 2. Gastropodensteinkern.

Beide aus den Eurydesmaschiefern der Dwykaschichten van Gaus und Marienthal, Bez. Gibeon, S.W. Afrika.

16. LES FORMATIONS DU KARROO A MADAGASCAR.

PAR

H. BESAIRIE.

Les formations du Karroo ont un gros développement dans l'Ouest de Madagascar, où elles occupent une place importante parmi les terrains sédimentaires. Je prendrai le type de ces formations dans le Sud-Ouest de l'île ou, entre Benenitra et Betioky, elles se présentent de la manière la plus complète. On peut distinguer 3 groupes séparés par des discordances et présentant des facies distincts.

I. LES FORMATIONS DU KARROO DANS LE SUD-OUEST.

Le groupe de la Sakoa.

Je propose de donner le nom de groupe de la Sakoa aux formations ci-dessous, anxquelles la présence de couches à charbon, particulièrement bien connues le long de la rivière Sakoa, donnent une importance économique considérable.

Schistes noirs et conglomérats.—La série sédimentaire la plus ancienne est formée par des couches de schistes noirs, d'une puissance atteignant jusqu'à 150 mètres, et où s'intercalent deux niveaux de conglomérats avec quelques bancs gréseux. Les schistes noirs sont très argileux; aux affleurements, ils se décomposent en paillettes, parfois en boules. Ils renferment quelques empreintes de *Schizoneura.* Les conglomérats sont formés de blocs cristallins, souvent de grosse taille, à contours anguleux, noyés dans une pâte argileuse ou gréseuse.

Les couches à charbon. Ces couches, puissantes d'une centaine de mètres, reposent directement sur les schistes noirs. Elles renferment de nombreuses couches de charbon dont les affleurements sont connus sur une longueur de plus de 100 km. Le charbon se répartit en deux faisceaux de bancs. Le faisceau inférieur renferme des couches dont l'épaisseur atteint 3 et 4 mètres, et de nombreuses petites couches. Le faisceau supérieur montre sur une longueur de 50 km. deux grosses couches qui ont jusqu'à

8 mètres de puissance. L'étage renferme, en outre, des grès mi-grossiers à feldspaths blancs, et quelques lits schisteux qui ont fourni quelques empreintes: *Gangamopteris major G. Cyclopteroides Feistm. Glossopteris, Schizoneura.*

La série rouge inférieure. Cette série recouvre les couches à charbon avec une legère discordance. Elle est formée d'argiles rouges et de grès verdâtres, mi-grossiers, à feldspaths roses. On y rencontre des débris de bois silicifiés. La partie supérieure montre des grès grossiers passant à des conglomérats. Ces couches ont une épaisseur de plusieurs centaines de mètres.

Le groupe de la Sakamena.

Au-dessus du groupe de la Sakoa, vient, en discordance très nette, un épais complexe schisto-gréseux débutant par un conglomérat de transgression puissant de plusieurs mètres et atteignant parfois 20 et 30 mètres.

Le conglomérat est formé de galets cristallins arrondis; il renferme des blocs d'un calcaire sédimentaire sur lequel nous reviendrons. Il est connu depuis le sud de Betioky jusqu'au nord de Benenitra, c'est-à-dire sur une longueur de près de 200 km.

Les couches de Sakamena proprement dites, s'étendent sur une très grande longueur et affleurent par endroit, sur des largeurs de 20 km. Elles sont épaisses de plusieurs centaines de mètres. Des grès en dalles, des psammites alternent avec des schistes argileux verdâtres. On y connait depuis longtemps l'existence de *Glossopteris indica* sur la Sakamena; j'ai recueilli sur les rives de cette rivière diverses empreintes de *Glossopteris* et de *Schizoneura.* A l'Eliva, un nodule gréseux renferme *Schizoneura* cf. *gondwanensis* Feistm. La région de l'Eliva est riche en nodules fossilifères. J. Pivetheau y a reconnu: *Hovasaurus Boulei* Piv., *Tangasaurus Menelli* Haughton, *Coelurosauravus Eliveneis* Piv, *Atherstonia Colcanapi* Priem. La partie supérieure de l'étage est formée de grès verts se délitant en grandes dalles, et où s'intercalent quelques lits d'argiles bariolées. Dans la région Nord de Ranohira et jusque vers Maevetanana, ces couches renferment un niveau à plantes où Zeiller a reconnu: *Schizoneura* cf *gondwanensis, Noeggerathiopsis* cf *lacerata* Feistm. *Cladophlebis remota* Presl, *Lepidopteris Stuttgartiensis* Brongt., *Danocopsis marantacea* Presl, *Taeniopteris magnifolia* Rogers, *Voltzia heterophylla* Brongt.

Un peu au-dessus, les grès de la Menamaty ont fourni des débris de reptiles que J. Pivetheau a rapporté au genre *Rhinesuchus.* J'ai pu m'assurer que le niveau à plantes se trouve au-dessous des grès à reptiles: il s'ensuit que l'attribution de cette flore au Keuper (Zeiller) ne saurait être maintenue.

La série rouge supérieure. Au dessus des couches de Sakamena vient une formation assez irrégulière d'argiles rouges et parfois bariolées alternant avec des grès tendres et jaunâtres.

Le groupe de l'Isalo.

Le groupe de l'Isalo, presque exclusivement gréseux, repose avec une légère discordance sur le système de la Sakamena. On y rencontre des bois silicifiés, parfois très abondants. A la partie supérieure on trouve des argiles bariolées. Ces grès, parfois assez tendres, ont une grande constance d'aspect sur de larges étendues. Dans le sud-ouest ils forment la pittoresque chaîne dechiquetée de l'Isalo.

II. Extension dans Madagascar.

Le groupe de la Sakoa est uniquement localisé dans le sud-ouest. Il affleure depuis l'Imaloto jusqu'a la hauteur du Vohibazaha. Vers le sud il est recouvert par les formations mésozoiques transgressives.

Le groupe de la Sakamena s'étend depuis le Vohibazaha jusqu'au nord d'Ankavandra. Dans la région de l'Imaloto, il recouvre transgressivement les séries inférieures et s'étend sur les schistes cristallins qu'il surmonte régulièrement jusqau'au sud-ouest d'Ambatomainty où il disparait sous les formations isaliennes. Il reparait néanmoins à la bordure des schistes cristallins dans la région de Maevetanana. Ce groupe affleure encors, à la faveur d'un plissement anticlinal, dans la région de moyen Ranobe où il montre des couches de charbon.

Le groupe de l'Isalo affleure depuis la haute Sakamena jusqu'à la pointe nord-est de l'île. Dans la zone comprise entre le Manambole et le Manambao il présente de puissantes imprégnations bitumineuses et est recoupé par de multiples dykes éruptifs. Dans le nord de Madagascar c'est encore le groupe de l'Isalo qui vient recouvrir les schistes cristallins mais il comporte ici de nombreuses et parfois puissantes intercalations marines.

Les transgressions marines dans le Karroo de Madagascar.

Dans le sud-ouest de Madagascar, les intercalations marines sont nombreuses dans le Karroo. On les connait à l'extrême sommet du groupe de la Sakoa où des lentilles calcaires s'allongent au dessus de la série rouge inférieure. La transgression limnique du système de la Sakamena a demantelé ces assises, et l'on rencontre des brèches calcaires et des galets calcaires dans le conglomérat de la base du groupe. En outre, le groupe de Sakamena comporte à des hauteurs diverses de nombreuses intercalations de calcaires marins.

La faune la plus intéressante de ces calcaires se trouve aux environs de Vohitolia (37 km à l'Est de Betioky). J'ai trouvé là, au sommet de la série rouge inférieure des calcaires fossilifères qui ont été etudiés par G. Astre. Ce paléontologiste a reconnu: *Productus* cf *curvirotris* Schellwien, *Spirifer* cf *rectangulus* Kutorga, *Avicula* sp. *Scaldia* sp., *Soleniscus* sp.

Au même niveau, mais un peu plus au nord, sur la rive gauche de la Sakoa et jusqu' au mont Hatakaliotsky, j'ai ramassé également des calcaires fossilifères sur lesquels J. Cottreau a bien voulu me donner des renseigements suivants: des calcaires noirs renferment des débris de poissons (écailles ganöides plissées, rayons de nageoires) des pélécypodes de petites tailles dont la forme et l'ornamentation rapellent le genre *Allorisma* King, des moules internes d'un gastropode de taille petite ou moyenne qui est peut-être une éspèce du genre *Loxonema;* des calcaires gréseux rose sont pétris de pélécypodes qui paraissent appartenir a une éspèce du genre *Myalina* de Kon.

Le sommet de la série rouge inférieure, et aussi plusieurs nixeaux du groupe de la Sakamena renferment des calcaires où l'on a cru voir autrefois des *Syringopora*. Des échantillons de ces roches, provenant du Ianapera, ont été communiqués à Delépine et Edwards. Ces Geologues pensent pouvoir rapporter ces organismes à des algues calcaires du groupe des Dasycladidés, voisines, sinon identiques à *Anthracoporella*.

Dans le nord de Madagascar, les intercalations marines sont beaucoup plus nombreuses. En complétant les dénominations de P. Lemoine et de H. Perrier de la Bathie, on peut donner la succession suivante:

5—Grès d'Antsalova (Antsakay à Tsaramborano).

4—Grès de Boriravina et argiles d'Ambararatra.

3—Argiles d'Anaborano sur Ifasy à Ambarabanja.

2—Grès du Mamoro.

1—Argiles d'Ankitokazo.

0—Schistes cristallins.

Les argiles d'Ankitokazo, localisées sur une faible étendue au voisinage du village d'Ankitokazo, renferment une faune assez riche décrite par Mme Vaillant Couturier: *Cyclolobus Walkeri* Drein., *Medlicottia Wynnei* Waag., *Xenaspis carbonarius* Waag, *Hungarites*. Cette faune permienne est vraisemblablement contemporaine du groupe de la Sakamena. Les grès du Mamoro, sans fossiles, ont un faciès fluviocontinental.

Les argiles d'Anaborano, depuis Ambanja jusqu'à l'Andavakoera renferment des nodules à poissons et à ammonites. H. Douville a dècrit: *Cordillerites* cf *angulatus, Ophiceras Dieneri, MeeKoceras* cf *gracilatis, Flemingites* cf *Russeli, Cladiscites, Johannites?, Tirolites, Otoceras*. Priem, Merle et Fournier ont reconnu de nombreux poissons: *Coelacanthus Madagascariensis, Gyrolepsis? Gillioti, Ecrinisomus Dixoni, Semionotus Labordei, Pristisomnus Merlei, etc.* A Anaborano, les argiles à nodules, puissantes de 200 à 300 mètres recouvrent directement les gneiss. A l'Andavakoera, ces argiles recouvrent aussi les gneiss, mais leur puissance est bien réduite. Du Tsaramborano jusqu'à l'Océan Indien, les gneiss sont recouverts par une petite épaisseur de grès surmontés par des argiles et des schistes très argileux où J. Cottreau a décrit: *Flemingites compressus, Meekoceras, Aspidites.*

Au-dessus de ces couches à poissons et ammonites vient un épais complexe gréseux, avec quelques intercalations schisteuses et argileuses que je propose de classer dans le groupe de l'Isalo.

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17. THE KARROO OF THE LOWER SHIRE-ZAMBEZI AREA.

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with an Appendix on the Fossils

BY

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Part I. The Sedimentary Rocks.

INTRODUCTION.

Previous Work. Brief accounts of the geology of the territory lying on either side of the Anglo-Portuguese Border have previously been published, but in the present paper the Karroo of the Lower Shire-Zambezi region is described as a whole.

In 1910, as part of their Mineral Survey of the Nyasaland Protectorate, A. R. ANDREW and T. E. G. BAILEY[1] gave an account of the Karroo lying

[1]. Q. J. G. S., Vol. LXVI, 1910, p. 216.

between the Lower Shire and the Anglo-Portuguese Border to the west. Excluding the uppermost division of pebbly sandstones occurring near Sinjal, now known to be of post-Karroo age, the total thickness of the Karroo was estimated by these authors to be approximately 25,450 feet. This estimate was probably unduly high, and further reference will be made to it in a later paragraph. The groups recognised included, in ascending order a group of coarse boulder-beds (450 ft.), a Lower Sandstone Group (6,000 ft.), a Shale Group (4,000 ft.), an Upper Sandstone Group (10,000 ft.) and a Lava Group (5,000 ft.). The Upper Sandstone Group was described as consisting only of a great thickness of massive sandstones or grits, but in the course of the present more detailed survey it has been possible to sub-divide this group into series of beds, three of them fossiliferous, which may be compared with the Middle and Upper Karroo of Rhodesia. The Karroo lavas, of which only the basalts were recognised, were shown to outcrop extensively on the Portuguese side of the Border and to extend into Nyasaland as a large semi-circular area measuring about 19 by 8 miles.

In 1920 R. Anthoine and J. Dubois[2] described the country between the Anglo-Portuguese Border and the Zambezi; these authors recorded buff and greenish shales, with plant remains, some distance below the base of the lavas, but they were evidently unaware of the existence of Andrew and Bailey's paper, for in the two sketch-maps accompanying their account they show the basalts and the immediately preceding beds to be confined wholly within the Portuguese side of the Border; moreover, they included the Lupata Volcanics within the Karroo, and did not recognise the intervening series of sandstones[3].

A year or two later the area was included within a map published by the Société Minière et Géologique du Zambèze[4]; on this sheet Andrew and Bailey's mapping received recognition, but the Karroo and the post-Karroo lavas were still mapped together as one group.

Total Thickness of the Karroo. The estimation of the total thickness of the Karroo is a question that presents considerable difficulties; in the first place no satisfactory topographical maps of the area are available, and the beds themselves have been extensively faulted during two or more periods; moreover, the greater part of the strata consists of coarsely current-

[2]. C. R. XIII Congr. Géol. Inter., 1922, p. 751.

[3]. See F. P. Mennell, Geol. Mag. lix, 1922, p. 169, and F. Dixey, Geol. Mag., lxvi, 1929, p. 241.

[4]. This map was based on observations made by Anthoine, Dubois, Hautart and others during the years 1920-22.

bedded pebbly sandstones and grits, of which it is impossible satisfactorily to estimate the thickness. ANDREW and BAILEY, and also R. M. CRAIG, considered the total thickness to be about 25,450 feet, but the area has since proved to be more extensively faulted than these authors realised; I am myself inclined to think that an estimate of 18,000 feet would more closely approach the true value, but even this is much in excess of the maximum figure of 5,800 feet suggested for the Upper Zambezi Valley[5]; the unusual thickness of the Karroo in the present area must accordingly be regarded as a local phenomenon, which is non-theless parallelled in Cape Colony where a total thickness of 26,800 feet is recognised.[6]

The Faulting of the Karroo. The boundary of the Karroo and the older rocks is almost invariably a faulted one, and along the eastern margin of the outcrop the downthrow must amount to many thousands of feet; innumerable smaller faults cut across the Karroo in various directions. The major faults are sometimes in the nature of shatter-belts, of which the fault-rock consists of banded and much-brecciated, highly siliceous rock, which in places is intimately associated with a pale grey felsite containing numerous fragments of the adjacent gneisses. These fault-rocks, as at Namalambo and Mangalangala, frequently give rise to steepsided ridges several hundred feet in height, and such ridges are occasionally seen to traverse the Karroo outcrop itself. The silica of the faults is often accompanied by calcite; these two minerals may be present in widely varying proportions, and they may show varying relations one to the other; for example, they may be interbanded, interlaminated, or closely intermixed, and they may exhibit several stages of brecciation and cementation. Veins of this character are locally well developed within all stages of the Karroo, and they are considered to represent a hydrothermal phase that followed on the extrusion of the felsite. The silica sometimes contains much pyrites, and the veins themselves have occasionally yielded a little gold.

Faulting on a smaller scale has taken place subsequent to the deposition of the post-Karroo sediments and lavas, and many of the later faults are doubtless to be attributed to the Rift Valley movements.

In the following table the Lower Shire-Zambezi succession is compared with that of the Upper Zambezi area; the presence of *Rhexoxylon africanum* in beds immediately overlying sediments assigned to the Lower Beaufort indicates that the Middle and Upper Beaufort are absent from at least the Lower Zambezi area.

5. A. L. DU TOIT, Geology of South Africa, p. 204.
6. *Op. cit.*

System	Series	*Lower Shire-Zambezi Area.*[7]	Approximate thickness in feet.	*Upper Zambezi Area.*[9]	Approximate thickness in feet.
KARROO SYSTEM	STORMBERG SERIES.	Basalt lavas	600		
		Rhyolitic lavas	400		
		Basalt lavas	3,500	*Batoka Basalts*	2,000
		Red Sandstones. with Upper Stormberg dinosaurian remains.	150 to 750	*Forest Sandstone*	210
		Upper Sandstone, with *Dadoxylon* sp. and *Rhexoxylon africanum.*	3,000	*Escarpment Grits* (and Somabula Beds).	300
	BEAUFORT SERIES. (LOWER BEAUFORT).	*Red Marls,* with fish scales, *Palaeanodonta,* spp., *Cyzicus,* and (in *Schistes de Mpiusa*[8] *Vertebraria and Glossopteris indica.*	1,500	*Madumabisa Shales*	700
		Middle Sandstone (Grès de Tete).	1,500	*Upper Wankie Sandstone*	200
	UPPER ECCA	*Upper Shales, Tapasa Sandstones* (*Grès de Matintè.*[8]) *Lower Shales,* with an Upper Ecca flora.	3,000	*Lower Matabola Beds*	100
	MIDDLE ECCA	*Lower Sandstone*	4,000	*Lower Wankie Sandstone.*	200
	LOWER ECCA.	*Mwanza Shales*	350		
			18,000		3,770

[7] The Middle Sandstone to the Upper Red Beds, inclusive, of this classification, comprises the "Upper Sandstone Group" of A. R. ANDREW and T. E. G. BAILEY (Q.J.G.S., 1910, p. 213), and the Lower and Upper Shales and the Tapasa Sandstones include the "Shale Group" of these authors.

[8] ANTOINE ET J. DUBOIS, C.R.XIII Congr. Géol. Inter., 1922, p. 751.

[9] A. L. DU TOIT, "Geology of South Africa," p. 204.

The Karroo of the Lower Shire-Zambezi region bears interesting relations to that of Cape Province as well as to that of Rhodesia, and it has been of considerable assistance also in correlating the Karroo of the northern areas with that of the south. These questions are discussed in greater detail in a separate paper dealing with the correlation of the Karroo north of the Zambezi.[10]

The Mwanza Shales.

In the Sumbu area about 4 miles west of the Mwanza River a series of green and purplish thin-bedded shaly sandstones with reddish sandy clays is exposed in the core of a large anticline in the Lower Sandstone. No fossils have been found in these beds, but in view of the great thickness of the Lower Sandstone and of the apparent similarity of the Mwanza Shales to certain of the Lower Ecca shales of Cape Province and of South-west Africa, they are provisionally assigned to the Lower Ecca.

The Lower Sandstone.

The Lower Sandstone is best exposed along the Telegraph track between the Mwanza and the Nkombedzi wa Fodya; it here gives rise to a broad, corrugated and rocky ridge, of which the constituent strata on the south-western side dip south-south-west beneath the Sumbu coalfield. The beds appear to consist wholly of thick-bedded coarse grey and white grits, current-bedded and locally pebbly; the total thickness of the series is of the order of 4,000 feet. No fossil wood is recorded from the Lower Sandstone.

The Shale Group.

The Shale Group is most satisfactorily exposed in the Sumbu area along the bed of the Nkombedzi wa Fodya and its tributaries, and in the area west of Nyatanda Hill. The remaining outcrops comprise the Chilimba area; the Tangasi area along the western foot of Namalambo ridge; the upper Nachipere, south-west of Port Herald; and the upper Nyakale and Zimbawe areas along the western foot of the Port Herald Hills. Probably also a concealed outcrop of small extent exists beneath the alluvium and the Lupata Sandstones occupanying the floor of the Shire Valley west of the line of the Mwanza Fault.

Consideration of the complete series at Sumbu and west of Nyatanda indicates that the thickness of the Shale Group is very great, probably near 3,000 feet; Andrew and Bailey, who did not recognise the complete sequence at Sumbu, estimated the thickness to be about 4,000 feet, and

[10]. See the next paper in this volume.

R. M. Craig considered it to lie between 3,000 and 5,000 ft. Even if the estimate of 3,000 ft. be accepted, this is still much in excess of the thickness recognised in Rhodesia.

The Shale Group of the Sumbu area may be divided into Upper and Lower Shales separated by a thick series of sandstones; this series, which may be termed the Tapasa Sandstone from the name of the broad ridge to which it gives rise, would appear to be equivalent to the "Grès de Mantinte" of the Tete coal basins.[11] A similar sandstone is present in the Nyatanda outcrop.

The Lower and the Upper Shale divisions each consists of a variable series of interbedded grits, sandstones, mudstones, grey shales, black carbonaceous shales, and coal seams; the shales locally contain nodular beds of iron-stone. The exposed coal seams, with included shale bands, generally range from 3 to 12 feet in thickness. The Shales are traversed by numerous sills and dykes of dolerite.

Towards the top of the Upper Shale division red sandy marls and brown and grey sandstones are developed to the exclusion of the shales, and by the intercalation of grey grits these pass up into the Middle Sandstone; these transitional beds are exposed along the Tangasi River several miles south of Namalambo Hill.

The Shale Group as a whole has yielded the following flora, which indicates an Upper Ecca to Lower Beaufort age.

Dadoxylon arberi.
Glossopteris indica.
G. browniana.
G. retifera.
G. angustifolia.
G. ampla.
Vertebraria sp.
Schizoneura gondwanensis.
Noeggerthiopsis sp.

Nachipere outcrop. Near the head of the Nachipere is a small outcrop of Karroo sediments that Andrew and Bailey[12]) regarded as a basal division older than the Lower Sandstone. But although no satisfactory information is available as to the relation of these beds to the Karroo of the main outcrop they may in all probability be referred to some part of the Shale Group, for in the Tete coalfield also sediments of this group are known to rest directly upon the crystalline rocks.

The outcrop is about three miles long in an east and west direction and three-quarters of a mile in width; it lies along the southern foot of Mbungwa Hill and runs parallel with the upper Nachipere at a distance of one to

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[11] R. Anthoine et J. Dubois, C.R. XIII Congr. Geol. Inter., 1922, p. 750.
[12] Q. J. G. S., Vol. lxvi, 1910, p. 217.

two miles. The beds rest unconformably upon the Nachipere Series, and appear to represent a small basin of deposition rather than a down-faulted area; no drusy quartz-rock or rhyolite such as accompany the Karroo boundary faults elsewhere have been observed along the margin of the sediments, although these fault rocks are sometimes seen to cut the neighbouring crystalline schists.

The sediments consist mainly of thick-bedded grits, which are locally pebbly and may sometimes contain boulders up to 18 inches in length. Coal shales are interbedded with the grits at several horizons, but they have not been observed to exceed about 20 feet in thickness. The general dip is about 30° to directions between north and east-north-east, and the total thickness exceeds 1,000 feet.

The Middle Sandstone.

The Middle Sandstone of the present classification consists of the lower part of the "Upper Sandstone" of Andrew and Bailey; and corresponds in part at least to the Grès de Tete of Anthoine and Dubois. The total thickness appears to be not less than 1500 ft.

No satisfactory exposure of the Middle Sandstone as a whole has been observed; the transitional red marly beds at the base, together with the succeeding grey grits and pebbly sandstones, may be seen along the Tangasi River south of Namalambo Rill, while light and dark greyish grits and sandstones, probably comprising much the greater part of the division, crop out from beneath the Red marls south of Mbuzi, and are overlain to the east by boulder beds belonging to the Lupata Sandstones. The beds consist mainly of the thick-bedded and coarsely current-bedded grey grits and pebbly sandstones that comprise a large part of the Karroo sediments of this area, but towards the base, as exposed along the Mbuzi-Terere road, they include many thin-bedded sandstones, often iron-stained and in places highly ferruginous.

No fossils have been observed in the Middle Sandstone.

The Red Marls.

The Red Marls are typically exposed along the southern bank of the Nkombedzi wa Fodya from Mbuzi to Syampanja, and thence southwards for 7 miles past Chipusi Hill and Chidimba as far as the Pwadze. Owing to their non-resistant nature the outcrop of the beds has been eroded into a broad shallow depression, bounded by the relatively resistant Middle and Upper Sandstones. The beds here attain a thickness of about 1500 feet.

A second outcrop occurs as a vaguely-defined north and south strip about 5 miles west of Namalambo Hill, and a third is faulted against the western side of the Zimbawe coal measures.

As exposed west and south-west of Mbuzi the beds comprise principally a series of soft-weathering pebbly marls and sandstones; grey and pink calcareous concretions are frequently associated with the marls, and pale grey limestones and greenish and buff-coloured calcareous shales occur at several horizons; there are also a few resistant beds of grit and of quartzite that give rise to steep-sided, parallel ridges. Numerous sills of basalt occur within these beds (see below, p. 10).

The prevailing colour of the series is due to the weathering of certain of the soft pebbly and argillaceous sandstones, and to the frequent occurrence of dark red sandy and pebbly marls, the latter sometimes pass into purplish marls, or are associated with pale-green or mottled red and green marls.

Fossil plants, mainly in the form of fragments of fossil wood and of roots, are represented in all these sediments.

The calcareous beds, which appear to represent the "Schistes de Mpiusa" of ANTHOINE and DUBOIS, are best exposed in the upper Nsungwe and Machulera streams between Chipusi Hill and Chidimba. In the Nsungwe Stream the following section of fossiliferous beds occurs near the top of the Red Marl series:—

	Strata.	*Thickness in feet.*
5.	Grey calcareous shales	4
4.	Quartzitic grit	4
3.	Green calcareous shales, weathering yellow-brown, with beds of soft argillaceous sandstone and of compact argillaceous limestone	20
	At the base, calcareous shales, and light-coloured and calcareous sandstones, with lamellibranchs (if *Palaeanodonta*), and a few ostracods. A few feet above these, green and brown shales with plant remains and fish scales.	
2.	Irregularly-bedded grey fragmental limestones with shale partings	5
	(An Analysis of the limestone shows CaO, 29.62 per cent; MgO, 19.70 per cent; SiO_2 Al_2O_3, etc., 6.30 per cent.	
1.	Current-bedded pebbly grit, thin-bedded and calcareous towards the top	10

These beds are underlain by a succession of red marls, sandstones, and grits.

A similar section is exposed in Machulera Stream, rather less than a mile to the south; moreover, several hundred yards lower down this stream,

probably at a slightly lower horizon, there occurs the following additional section which has yielded ostracods, lamellibranchs, and plant remains:—

	Strata.	*Thickness in feet.*
4.	Thin-bedded sandstones	5 (top not exposed)
3.	Hard, coarse, quartzitic grit	4
2.	Soft sandy and calcareous shales weathering greenish and buff; brown plant remains occur throughout, together with scattered lamellibranchs	25
	(*Palaeanodonta* sp.)	
	Towards the base are dark bluish-grey, soft, shaly limestones, crowded with ostracods, and yielding a few well-preserved *Cyzicus* of *minuta* (See also Appendix p.....)	
1.	Soft thin-bedded argillaceous sandstones, weathering buff and yellowish-brown, with many plant fragments	8 (base not exposed)

These beds are underlain by a thick series of red sandy marls and grits.

Although the fauna of the Nsungwe and the Machulera beds bears a general resemblance to that of the Lower Beaufort beds of North Nyasa, it is not of itself sufficiently definite to fix the age of the Red Marl series, but when the *Vertebraria* sp. and *Glossopteris indica of the Schistes de Mpiusa* are added to the list of fossils, there is satisfactory evidence that the series may also be referred to the Lower Beaufort. Since the Red Marl series is directly overlain by sandstones yielding *Rhexoxylon africanum*, although without obvious break, it may be taken that the Middle and Upper Beaufort are unrepresented in the Lower Shire-Zambezi area.

The Red Marl series has been invaded by numerous intrusions of basalt, usually in the form of sills and laccolites; the larger of these intrusions, as seen along the south bank of the Nkombedzi wa Fodya west of Mbuzi, and also immediately east of Chiromo, probably exceed 100 feet thickness. Although obviously of an intrusive nature, these are sometimes highly vesicular, and consequently their weathered outcrops are frequently strewn with innumerable agates, which usually show either a red or a blue coloration.

Moreover, there occur numerous sheets of calcareous and siliceous rocks that are probably due to hydrothermal activity following upon the extrusion of the Karroo lavas. These rocks usually take the form of interbanded grey limestone and dark-grey to black cherty silica, and, since they almost invariably extend along the bedding of the enclosing rocks, they have at

first sight every appearance of having been laid down contemporaneously with the sediments; fortunately, they may sometimes be observed to cut directly across the bedding. The silica of these rocks may occur within the limestone as even bands, as lenticles, or as irregular masses; or it may be give rise to a compact, even-grained siliceous limestone. The deposits are sometimes many feet in thickness, although the individual silica bands rarely exceed two inches in width.

The Upper Sandstone.

The beds now described comprise the upper part only of the "Upper Sandstone" of Andrew and Bailey; they have yielded *Rhexoxylon africanum*, and they are equivalent, at least in part, to the Escarpment Grits and the Somabula Beds of Southern Rhodesia. They consist essentially of a lower series of white thin-bedded sandstones and an upper series of grey pebbly grits, and the total thickness of the division is about 3,000 feet.

The lower series, which attains a thickness of fully 1,000 feet, is well exposed in the area south-west of Mbuzi, and also west of Zimbawe; in each case the sandstones near the base give rise to a well-defined and highly-battlemented scarp, generally ranging from 100 to 200 feet in height, that overlooks the relatively low-lying outcrop of the preceding soft marly sandstones and the Red Marl series. In general the sandstones of the scarp are fairly soft, thin-bedded, light-coloured and strongly current-bedded; some beds are silicified, and others are slightly calcareous, while iron-staining is variably developed. Beds of grit and of pebbly sandstone are often well developed at the base and sometimes also at other horizons; these lowest beds have yielded *Dadoxylon* sp. and *Rhexoxylon* sp.

The upper series consists of a monotonous succession of grey, coarsely current-bedded, pebbly grits; the pebbles are frequently more numerous towards the top, where they consist principally of quartz and of various hard gneisses and schists. These beds are well exposed in the vicinity of Panga Hill and Chirunda Hill, and also further south eastwards of the basalt margin.

The uppermost beds, which between Panga and Chirunda Hill are hard, white and quartzitic, pass upwards by alternation into the Red Sandstones.

Apart from the lowermost beds immediately above the Red Marls, the Upper Sandstone has yielded fossils only from a horizon near the top, where however an abundant fossil wood flora is developed. The fossil logs and root stocks frequently attain a diameter of as much as two feet, and the zone characterised by these remains can be traced for many miles parallel with the margin of the basalt. The principal forms observed include

Rhexoxylon africanum.
R. tetrapteroides?
R. sp.
Dadoxylon sp.
Gymnosperm wood.

Similar beds crop out on the Zambezi above the Lupata Gorge beneath the Red Sandstones and the basalt.

The Red Sandstones.

The Red Sandstones vary in character as they are followed from north-west to south-east across our area; for example, north-west of Chirunda Hill they consist principally of grey quartzites and white or buff sandstones, with but a small development of the red marly beds, whereas south of this point the quartzites die out and the red marls and associated sandstones come in to an increasing extent. This change is clearly reflected in the topography of the area, for while in the north-west the hard quartzites and grits form a well-defined ridge, several hundred feet in height, that overlooks the low ground due to the earlier basalts, south of Chirunda Hill the red marls and associated beds have proved much less resistant than the basalts, which accordingly, as at Chiradzulu Hill, form the capping of a pronounced scarp about 400 feet in height.

In spite of this variation, however, the series throughout is characterised by sandstones containing a high proportion of well-rounded grains of the type occurring in desert sands, and on account of this and other common features it is regarded as being the equivalent of the Forest Sandstones of Rhodesia. The thickness of the quartzitic facies appears to be about 150 feet, whereas that of the marly facies increased to a thickness of about 750 feet near Chimpundu.

The quartzitic facies succeeds the hard white quartzites and grits at the top of the Upper Sandstone by alternation with these beds. For example, in the Mafume section east of Murukanyama, immediately below the base of the basalt, there occur the following beds in descending order:—desert sandstone, friable yellowish grit, with small pebbles, grey even-grained quartzites, fine-grained white quartzites and buff sandstones with plant remains and grey pebbly grit. At Panga Hill a similar, but apparently thicker series is present, and it includes a considerable development of very fine-grained, hard cream and buff quartzite, with well-rounded grains and with plant remains resembling those of the Mafume section: below these come grits, white current-bedded quartzites, sandy marls with fragments of fossil wood, and finally thick-bedded grey pebbly grits. Mr. F. P. Mennell, who very kindly examined a number of hand specimens of these rocks, has informed me that in general the white and buff desert quartzites and silicified sandstones are indistinguishable in appearance from

the corresponding beds of the Forest Sandstones of Southern Rhodesia. The uppermost beds locally show signs of having been contemporaneously brecciated.

The uppermost desert sandstones and grits of this area sometimes contain lapilli as well as larger fragments of basalt, and the earlier flows of the succeeding basalts alternate with several beds of quartzitic sandstone; these intercalated sandstones, which have not been observed to exceed about 12 feet in thickness, are also of desert character.

Between Chirunda and Nyapanda Hill the marly facies of the Red Sandstones gradually increases in thickness, and no resistant beds of quartzite or of grit have been observed within it, although basalt sills and evidences of hydrothermal action are present much as in the Red Marls south-west of Mbuzi. The maximum width of the outcrop is about three quarters of a mile.

The series here consists essentially of soft red and white pebbly marls and sandstone, interbedded with soft thin-bedded grey and buff sandstones, which are slightly calcareous and of desert character. The marls frequently contain small quartz pebbles, and also grey and pink calcareous concretions; moreover, there are numerous fragments of fossil roots and a few of fossil wood. The sandstones near the base, particularly those of the Chiradzulu area, locally enclose nodules of grey limestone that extend parallel with the bedding. The buff desert sandstones, about 90 feet below the base of the basalt, have yielded fragmentary dinosaurian remains in two localities, namely about 1½ miles from Chimpundu on the Zimbawe road, and about 2/3rd mile further south; these fossils are considered by DR. HAUGHTON to indicate an Upper Stormberg age for the enclosing beds.

The succession is closed by a band of coarse grey pebbly grit; this grit, which is of the common Karroo type, increases in a southerly direction to a maximum observed thickness of 140 feet; it gives rise to a steep bluff which is capped by the earliest volcanic outbursts.

The Red Sandstones are present also above the Lupata Gorge where the Upper Karroo beds and the succeeding basalt strike across the course of the Zambezi. The series, which is apparently represented only by the soft reddish sandy and marly facies, is not well exposed and is in part faulted against the base of the basalt. Farther to the south, within the Barue border F. P. MENNELL[13] has observed an arkose with pink felspars and fine-grained pale buff sandstones similar to those of Chirunda Hill and Panga Hill.

The *volcanic rocks* succeeding the Red Sandstones are described in a separate paper (see below).

[13]. Geol. Mag. lix (1922), p. 166.

I would like to express my great indebtedness to Dr. S. H. Haughton for his kindness in describing the fossil shells I collected in the Lower Shire-Zambezi Area, and to Dr. John Walton and Miss M. L. L. Stirk, M.Sc., for their valuable determination of the fossil woods.

Appendix.

LAMELLIBRANCHS, PHYLLOPODS, AND OSTRACODS FROM THE KARROO OF THE LOWER SHIRE-ZAMBEZI AREA.

BY

S. H. Haughton, D.Sc., F.G.S.

Fossils from the Machulera Section.

Cyzicus cf. *minuta*. There are several valves of this Phyllopod, the average length being 6 mm. and the average width 4.5 mm. The number of ridges is variable, but there are certainly as many as 30 in one of the valves. The ridges are obscure near the umbo, and close together near the ventral border. The umbo is placed at one-third of the length of the shell from the anterior end. The ventral border is symmetrically convex. Hinge-line straight. Hinder end of carapace more strongly pointed than the anterior end.

The ornamentation consists of strong reticulation of polygonal pits, much as in *C. minuta*. The number of pits between any two consecutive ridges varies from 3 (near the ventral border) to 7 or 8. (Cf. Jones, Monograph, Pl. II, fig. 7).

The form differs from *C. exigua*, *portlocki* and *greyi*, all Permian forms. It agrees most with *C. minuta*—a Triassic form which has also been described by Deperet and Mazeran from the Permian of Autun.

These latter authors described an associated species—*lullyensis*—from the Permian of Autun, but I have not seen the description.

The specimens differ from R. Bullen Newton's Estheriella nyasana (Q.J.G.S., lxvi (1910), p. 244.) in the absence of radial striae. They are beautifully preserved.

Ostracods. The rock is crowded with small, elongate thin-shelled ostracods. They are elongate-oval in outline, varying to slightly kidney-shaped. The carapace is smooth. The characters are obscure; the valves show some agreement with those described by Leriche from the Congo as *Darwinula globosa* var. *stricta* Jones, or they may belong to the genus *Candona*. The length is about 1 mm.

Lamellibranchs. There are five or six rather imperfectly preserved specimens of a thin-shelled lamellibranch. The largest has dimensions about 13 mm. by 9 mm. The shape is oblong-ovate, unioniform; the umbo is somewhat anterior, and not very prominent. Hinge-line curved: no dentition visible, hinge probably toothless. Muscle scars not seen. Valves closed, ornamented by concentric striae.

From *Palaeomutela* the form is distinguished by the absence of a schizodont dentition, and is therefore probably to be looked upon as belonging to the genus *Palaeanodonta*. In view of the imperfect preservation, discussion as to its specific position would be unwise.

Palaeanodonta occurs in the Permian of Russia and of S. Africa. The form described as *Iridina* (?) *oblonga* by Jones from Maramura, Central Africa, may belong to this genus (fide Amalitzky).

Fossils from the Nsungwe Section.

Numerous casts of lamellibranchs in light-coloured sandstone. Preserved as they are, it is not possible to make out either the characters of the hinge-line or the shape of the muscle-scars, and therefore their exact identification is not possible.

The shells are somewhat rhomboid in shape with a slightly convex or straight ventral border, which is longer than the hinge-line. One of the largest shells has a length of 10 mm. and a height of 8 mm. The umbo is well in the anterior half of the shell. Shell moderately swollen at the umbo, which is broad, but does not stand high above the hinge-line. No distinct post-umbonal ridge, but a rounded angle where the lateral face passes over in the posterior face of the shell. Shell concentrically striated.

No cast shows any sign of dentition, a piece of negative evidence which leads to the conclusion that the shells may belong to the genus *Palaenodonta*. They are smaller and more swollen than those from the Machulera section, and do not seem to agree in shape with any of the described African forms.

Ostracods similar to those from Machulera occur on one slab.

The two sets of fossils show general similarity with those described by Bullen Newton from Nkana; but the species are distinct from the Nkana forms, and the beds may be of a different horizon.

Part II. The Volcanic Rocks—Basalts and Rhyolites.

In their account of the Karroo of the Lower Shire area Dr. A. R. Andrew and Mr. T. E. G. Bailey[14] showed that the Karroo basalts of Portuguese territory crossed into Nyasaland and gave rise to a semi-circular outcrop of which the diameter, extending along the Anglo-Portuguese Border.

[14] Q. J. G. S. Vol. lxvi, 1910, p. 217.

was about 19 miles in length. The group of lavas was considered to attain a thickness of 5000 feet, and to consist for the most part of vesicular basalt; certain of the lavas appeared to be andesites, and a block of banded rhyolite was seen, although not *in situ*. No tuffs of laterites were observed between the flows, but "at least one interbedded stratum of sandstone" was recorded from near the base of the lavas.

Subsequently F. P. Mennell[15] showed that the volcanic rocks of the Lupata Gorge were divisible into a lower series of basalts of Karroo age, and an upper series of rhyolitic and alkaline lavas apparently of late Jurassic or early Cretaceous age.

As a result of the more recent survey carried out by the present writer during 1927-28 it appears that the Karroo volcanic rocks of the Lower Shire-Zambezi area probably attain to a total thickness of 4500 feet; moreover, they comprise a lower series of basalts followed by rhyolites and then by an upper series basalts—a succession comparable in character with that of the Lebombo belt[16] along the borders of Portuguese East Africa west of Lourenço Marques. The lower basalts are locally interbedded with agglomerates and tuffs, as well as with several layers of standstone. The Karroo lavas pass beneath the Lower Lupata Sandstones, and these sediments in turn are overlain by the post-Karroo Lupata volcanics, which thin out in a south-easterly direction parallel with the Zambezi.

In general the outcrop of the Karroo volcanic rocks gives rise to country of greater elevation and of higher relief than that of the adjacent Karroo sediments; for example, the basalts of the main group culminate in Murukanyama Hill, rising about 1500 feet above the Shire, and also constitute the high watershed traversed by the international boundary; farther to the south-west rhyolites running parallel with the Zambesi stand up as a bold ridge that includes the Pumba, Kuche, and Niamaridzi hills; still nearer the Zambesi the Domue-Sarula ridge marks the outcrop of the south-eastern extension of the Lupata volcanics.

The Basalts.

The Karroo sediments immediately preceding the basalts are of desert character, and thus may be compared with the Forest Sandstones of Rhodesia. In places the uppermost beds, as well as those intercalated with the lower flows of lava, include lapillae and fragments of basalt. The few sandstones interbedded with the basalts are usually hard, quartzitic, and of a greyish colour, and individually they do not appear to exceed a thickness

[15]. F. P. Mennell, Geol. Mag., 1922, lix, p. 169; see also E. O. Teale and W. Campbell Smith, Geol. Mag., 1923, lx, p. 226, and F. Dixey and W. Campbell Smith, Geol. Mag., 1929, lvi p. 241.

[16]. J. M. Henderson, T.G.S.S.A., 1900, xii, p. 24. R. B. Young, ibid., 1920, xxii, p. 98.

Fig. 1. Communication No. 17.

Fig. 2. Communication No. 17

Fig. 1. Murukunyama (1,650 ft.) the highest of the Lower Shire basalt hills; view taken from the north, showing the successive flows.
Fig. 2. Basalt hills around the north-western foot of Murukunyama.

of about 12 feet; the character of the sandstones indicates that desert conditions continued throughout the deposition of at least the earlier beds. Where the desert accumulations are hard and quartzitic they give rise to a ridge that wraps around the basalt margin, but where they consist of soft buff sandstones and red marls they are themselves overlooked by the scarp of the lowermost basalts.

In general the earliest flows consist of dark, microcrystalline basalt; at Chiradzulu Hill a flow of this kind is overlain by a bed of purplish agglomerate, 25 feet thick, that contains masses of lava up to a foot in length; the agglomerate is succeeded by compact greenish-grey basalt that forms the summit of the hill.

In lithological and in field characters the basalts are fully in accord with the principal outcrops of these rocks in Rhodesia and South Africa.[17] The lavas are generally dark grey to bluish-grey or black in colour, but they weather to brown, chocolate, purple and greenish tints; they vary from compact fresh crystalline basalts to coarser, porphyritic, highly amygdaloidal and much weathered types, of which the vesicles are filled either with agate, chalcedony, and quartz, or with calcite and various zeolites. The larger flows attain a thickness of fully 100 feet, and the outcrops of the compact crystalline types tend to stand out as a series of parallel ridges.

Although in general the lava flows succeeded one another too rapidly for much weathering to take place, yet weathered surfaces are occasionally found, and upon some of these rest thin beds of red, fine-grained, laminated sandstones and gritty tuffs; a succession several times observed consisted of a much-weathered surface of amygdaloidal lava, followed by two to three of thin-bedded red sandstone and associated red ashes and tuffs, and then by a flow of compact crystalline basalt vesicular at the base.

Certain of the ashes were light in colour and of a fine porous texture; in one case leaf impressions were seen. The colours ranged through white and cream to mauve and pink, and locally to red. Beds of this type were usually two to three feet in thickness, but sometimes they were as much as 25 feet; they were observed at half a dozen or more different horizons.

As will be described in more detail below, at least one sheet of rhyolitic ash is interbedded with the basalts. This ash is locally silicified.

Coarse agglomerates, with included blocks sometimes exceeding a foot in length, were recorded from several horizons, and the beds in places were as much as 50 feet in thickness. Near the summit of Chigungwa Hill, about half a mile north of Murukanyama, a good example of a volcanic neck was exposed; it was 12 yards in diameter, and it consisted

[17]. A. L. du Toit, "Geology of South Africa," 1926, p. 238.

of dark blocks of highly vesicular lava of various kinds all embedded in and veined by a compact red basalt. The blocks varied from less than one inch to one and two feet in length, and one mass about four feet long was seen; they were continuous at the top with a bed of agglomerate 15 feet thick that surrounded the vent and thinned out on an earlier sheet. The neck penetrated a flow of fine-grained crystalline basalt and was overlain, together with the associated agglomerate, by a second flow of similar character.

This neck stood about 1000 feet above the base of the lavas, and agglomeratic beds were but occasionally seen at higher horizons; it would appear, therefore, that in this area as in South Africa centralised eruptions were of importance during the earlier part of the volcanic episode, whereas eruptions of fissure type predominated throughout the later stages. Furthermore, the vents and agglomerates are recognisable in an area in which both the lavas and the underlying sediments show a maximum thickness; these conditions are similar to those of the main Karroo basin of Basutoland,[18] where the strata are of comparable thickness.

In thin section the lavas are seen to consist principally of augite-labradorite basalts; they vary from granular holocrystalline, almost non-vesicular, types to porphyritic, highly vesicular, and largely glassy types. Nearly half of the 60 slides examined show more or less rhombic pyroxene, and one sixth of the slides contain olivine, although generally this mineral is present only in small amount. The mesostasis in the different cases reveals varying amounts of glass and of a final product of crystallisation that appears to be chlorophaeite; this mineral is observable also in a few hand specimens as small patches of a soft black earthy substance. The less basic basalts approach augite-andesite and augite-enstatite-andesite in composition, while other porphyritic, medium to coarse-grained, intersertal lavas are of tholeiite type. Several examples of dense, glassy, andesitic ashes were observed.

The felspar of the lavas is usually a medium labradorite, and a little interstitial orthoclase is present in some slides. The augite is generally granular, and it varies from pale brown to colourless. The rhombic pyroxene tends towards idiomorphism; generally it is pale green in colour, but the darker types are slightly pleochroic; in a number of slides it is more or less completely represented by bastite pseudomorphs. The olivine is mostly granular, although many larger idiomorphic crystals were observed; it varies from perfectly fresh to completely serpentinised forms. Magnetite is abundantly present as dust and as small grains and octahedra in nearly all the slides, but numerous large skeletal and rod-like crystals are developed; it is associated with varying amounts of haematite.

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[18]. T. W. Gevers. "The Volcanic Vents of the Western Stormberg. Trans. G.S.S.A., Vol. xxxi, 1928, p. 58.

To face page 137.

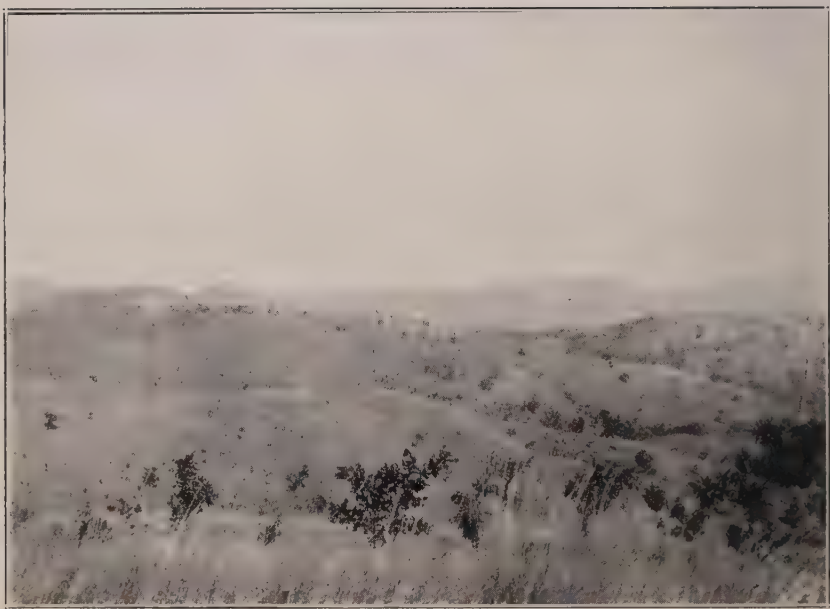

Fig. 3.

Communication No. 17

Looking towards the Zambezi from the Anglo-Portuguese Border; in the foreground and middle distance, the scarps of the basalt flows; in the far distance Niamaridzi scarp, marking the outcròp of the Karroo rhyolites.

The Rhyolites.

The only previous records of rhyolitic rocks in the present area are as follows:—

(a) Andrew and Bailey[19] recorded banded rhyolite from the basalt outcrop, but the fragment or fragments seen were not *in situ;* from my own observations on the ground I am inclined to the view that the specimen described was part of an intrusion rather than of a flow.

The same authors record also " very occasional quartz-porphyry dykes cutting the lavas "; while I have not seen dykes of this description in the area, I have observed many examples of small rhyolitic and felsitic intrusions.

(b) Mennell[20] recorded " an isolated sheet of columnar rhyolite " from the Lupata Sandstones of the Lupata Gorge, as well as rhyolites from amongst the Lupata Volcanics. These rocks are probably of late Jurassic or early Cretaceous Age.

The fieldwork of the last two years has demonstrated that two distinct but possibly related rhyolitic outbursts occurred in the area during Karroo and early post-Karroo times. The first of these resulted in the accumulation of rhyolitic lavas and pyroclastic rocks amongst the later Karroo basalts, and the second in the injection of rhyolites and felsites into the Karroo boundary faults. The second was followed, or even to some extent accompanied by, a hydrothermal phase that led to the formation of a complex series of siliceous and calcareous rocks.

The faulting of the Karroo probably took place shortly after the extrusion of the basalts and associated lavas; indeed, it might well have started before the close of Karroo times, as in parts of South Africa.

The early post-Karroo age of the later rhyolites is evident not only from their relation to the Karroo boundary faults, but also from the inclusion of numerous pebbles of these rocks within the Lower Lupata Sandstones. Moreover, in the Lower Ngoma River east of Sinjal the rhyolite accompanying an important Karroo boundary fault passes with the fault beneath the Lupata Sandstone. It will be convenient to describe the two groups of rhyolites separately.

(1) *The late Karroo Rhyolites.* The earlier group of rhyolites can be followed over the Karroo basalts for 30 miles, and for the greater part of this distance they lie half a dozen miles south-west of the Anglo-Portuguese Border; they give rise to a chain of hills that terminates 5 miles north of Sinjal and includes Pumba, Kuche, Niamaridzi and Chom-

[19]. Q. J. G. S., lxvi, 1910, p. 220.

[20]. Geol. Mag., lix, 1922, p. 169

bamwani ridges. The rhyolites followed directly upon Karroo basalts of ordinary type, and they vary from a maximum thickness of 400 feet at Kuche to about 200 feet at Chombamwani. They dip gently towards the south-west in apparent conformity with the basalts, and in the neighbourhood of Doa and Tumbu west of Niamaridzi they pass beneath basalts that outcrop in low ground over an area measuring about 5 by 2 miles; these later basalts, which are about 600 feet thick and of ordinary Karroo type, dip beneath the Lupata Sandstones running parallel with the Zambezi.

The lavas are predominantly mauve in colour, but red and mixed red and mauve types also occur, particularly towards the top. They are often of platy habit, and they frequently weather into small regular rectangular blocks. They include beds of tuff and agglomerate, as well as flow-brecciated and scoriaceous forms. The lavas themselves are usually porphyritic, vesicular, and felsitic to micro-crystalline in texture, although several glassy types have been observed; moreover, the more felspathic forms graduate towards trachyte. The uppermost flows are invariably of ropy and slaggy structure, and they present a remarkably fresh appearance; moreover, they are often brecciated, and hollows and caverns are developed beneath them.

The masses of lava frequently contain rounded cores of white to cream highly siliceous rhyolite, with relatively few phenocrysts, and their outcrop is sometimes strewn with large numbers of small red agates and carnelians.

Apart from the main group of lavas just described, there has been observed only one other certain case of contemporaneous rhyolitic activity within the basalts, and this occurs low down in the volcanic sequence. It takes the form of a series of bedded and sometimes laminated rhyolitic ashes, about 18 feet in total thickness, intercalated between normal Karroo basalts; they are exposed on the Chitui road about a mile from Saopa, where they give rise to a little ridge known as Mpiriantanda. The ashes are highly siliceous, flinty in appearance, and of a pale blue-grey colour weathering buff; in thin section they are seen to consist of innumerable minute angular fragments of quartz, felspar, and brownish glass, all embedded in a pale-grey mottled base that is feebly birefringerent. Many other isolated occurrences of brecciated and of banded rhyolitic rocks were observed on the basalt outcrop, but wherever their relations could be satisfactorily determined they were found to be clearly of intrusive character.

In thin section, the rhyolites are seen to contain phenocrysts of orthoclase, with relatively few of quartz; sphene is also represented, and there are many crystals of magnetite showing skeletal and spongy forms. The phenocrysts exhibit varying degrees of cloudiness and resorption. The groundmass is colourless to pale brown, but is rendered dusty by the presence of innumerable specks and microlites of magnetite. It is dom-

inantly microcrystalline to microlitic in texture, and in the coarser specimens ill-formed microlites of felspar are seen embedded in quartz. In general there are numerous small dark-brown and yellow-brown circular patches showing a tendency towards radial or spherulitic structure, and a few coarsely-spherulitic rocks were observed in the field. The vesicles, which are sometimes numerous, are generally infilled with quartz mosaic. Between crossed nicols the rocks usually show a marked patchy appearance, owing to the varying development of glassy and cryptocrastalline matter within the groundmass. Some specimens exhibit good flow banding, which is indicated by the development of bands of differing texture together with narrow streaks of quartz mosaic.

The general character of these rocks combined with their relation to the Karroo basalts suggests that they are contemporaneous with and probably related to the Lebombo rhyolites. These two occurrences, both situated on the eastern margin of the Continent, apparently constitute the only known acid lavas of Karroo age in South or Central Africa, but in Tanganyika and other areas yet farther north there are many instances of acid rocks intercalated amongst the basic lavas of presumed Karroo age.[21]

The late Karroo Rhyolitic Intrusions. The basalts underlying the main series of rhyolites are traversed by numerous rhyolitic intrusions, but the number of these intrusions becomes less and less with increased distance from the rhyolite lavas. Certain of them resemble the red rhyolites at the top of the main series of flows, and these intrusives as a whole are regarded as being closely related to the lavas.

In many cases the intrusives fill irregular fissures or possibly vents that appear to have been formed in the basalts with explosive violence, and within these exposures evidence for repeated activity can usually be seen. The dykes vary from a few inches to many yards in width, and occasionally several of them occur in parallel; but they rarely exceed 50 yards in total length.

It is not surprising therefore that a single outcrop will often yield many varieties of these rocks which, nonetheless, apart from the included masses of basalt, are all of acid character. Good exposures may be seen on the Chitui—Doa road about 2 miles west of the Anglo-Portuguese Border, and again near Wemba Stream 3½ miles from Doa. The specimens collected include black obsidian-like forms, as well as light-coloured flow-banded rhyolites. Other types are cryptocrystalline in texture and range in colour from white and black, to pink, red, mauve and green; these colours are sometimes variably interbanded and inter-brecciated in the

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[21]. See F. Dixey, "A Provisional Correlation of the Karroo North of the Zambesi." (See next paper in this volume.)

different specimens, with the result that some very striking effects are produced.

(2) *The early post-Karroo Rhyolites and Hydrothermal Rocks.* The major faults that brought the Karroo against the older formations, as well as many related minor faults and disturbances, are frequently marked by the presence of rhyolitic and felsitic intrusions. These intrusions are intimately associated with siliceous and to a less extent calcareous rocks that appear to represent a hydrothermal phase following upon the intrusive, and possibly extrusive, igneous phase. Accordingly, the outcrops of the larger faults and shatter-belts frequently take the form of a high ridge of light-coloured, banded, drusy, and much-brecciated quartz-rock, with which the parent igneous rock is often closely associated. The quartz-rock is generally pyritous, and in several instances it has yielded small quantities of gold.

The rhyolitic and felsitic rocks themselves are usually of a compact or porcellanous texture, and pale grey or blue-grey in colour; the more glassy varieties may be dark grey or black, and all types show varying degrees of iron-staining. A characteristic feature is the inclusion of abundant fragments of various extraneous rocks, which gives the rhyolites and felsites a pronounced fragmental or agglomeratic appearance; the included debris may be in such quantity as to constitute the greater part of the rock, and this, combined with the general absence of any sign of crushing, indicates that the intrusion was accompanied by explosive action; furthermore, the nature of the fragments shows that such action was repeated from time to time. The included fragments represent in varying proportions the adjacent country rocks, such as basalt, sandstone, and gneisses, together with different forms of the acid rocks themselves, such as flow-banded, compact, and dark glassy kinds. The fragments range from microscopic dimensions to a foot or more in length; many of them are angular or splintery, while others show varying degrees of absorption, corrosion, and recrystallisation. As seen in this section, the intrusives are principally of cryptocrystalline texture, but glass is usually present to a greater or less extent; the cryptocrystalline base is generally colourless or of dusty appearance, but the glass varies from pale brown to deep brown and black. Microlites of biotite and magnetite are common, but shreds of ferromagnesian minerals and of felspar are occasionally seen. Calcite and pyrites are almost invariably present.

South-west of Port Herald in the bed of a stream below the Lulwe lime-works and several miles distant from the nearest Karroo outcrop, the acid intrusives may be seen intersecting calcareous and other gneisses. Here, however, rhyolites of the type described constitute only the chilled, more finely crystalline, or more acid phase of other somewhat larger

intrusive masses. The relatively coarse rock, in which numerous deeply corroded fragments of extraneous rocks occur, consists of a microcrystalline felspathic base, with microlites of green mica and of aegirine, and patches of cryptocrystalline matter and quartz; there are present also rounded masses of dark glass, and phenocrysts of aegirine, acid felspar, and quartz, most of which are corroded and bordered by reaction rims; the pyroxenes are often bleached internally, but coloured bright green around the margin. Intermediate stages may be found between this rock and the wholly crypto-crystalline and glassy type.

It is a point of considerable interest that near the extreme northern end of Nyasaland, in the great fault that brings the Karroo of the North Rukuru River against the crystalline series, rhyolitic rocks again occur, and these are indistinguishable from those associated with the Karroo of the Lower Shire, nearly 450 miles to the south. Furthermore, in 6 other localities lying between these two areas additional intrusions of rhyolitic rocks have been observed within the crystalline series. Many of these rocks are indentical in character with specimens from the two groups of rhyolites just described, and there seems no room to doubt that they belong to the same phase or phases of igneous activity; moreover, they indicate that just as numerous minor vents were erupting over the Karroo area of the south, so elsewhere throughout what is now Nyasaland, over a linear distance of more than 500 miles, additional eruptions were taking place, although possibly only of local importance.

The Siliceous and Calcareous Fault-Rocks. Not only the igneous intrusions but also the associated siliceous and calcareous fault-rocks show many stages of brecciation and cementation. The silica and calcite of these rocks are present in widely varying proportions from place to place, and examination in thin section shows that the highly siliceous forms and even the igneous intrusions themselves are often intimately associated with calcite. A common rock type consists of interbanded grey compact limestone and grey or black cherty silica, and in this the bands may be regular or may take the form of parallel lenticles of silica embedded in calcite; this type is not only frequently present in the faults, but it shows also sill-like and dyke-like relations with the less resistant sediments, as well as with the tuffs and sandstones interbedded with the basalts. Other forms comprise finely banded silica and calcite, and these are usually stained in various shades of mauve, red, and brown; others consist of calcite only and exhibit varying degrees of banding, crystallisation, and staining.

A single fault or fissure sometimes reveals a wide range of these different rocks, and their relations may be still further complicated by brecciation, which in some cases appears to have been due partly to explosive action. A

good example of a complex occurrence of this kind, in which the rhyolite is also represented, may be seen two miles from Ngabu on the Saopa road, where the vent or fault intersects the basalt lavas.

EXPLANATION OF PLATES.

FIG. 1. Murukunyama (1,650 ft.), the highest of the Lower Shire basalt hills; view taken from the north, showing the successive flows.

FIG. 2. Basalt hills around the north-western foot of Murukunyama.

FIG. 3. Looking towards the Zambezi from the Anglo-Portuguese Border; in the foreground and middle distance, the scarps of the basalt flows; in the far distance Niamaridzi scarp, marking the outcrop of the Karroo rhyolites.

18. A PROVISIONAL CORRELATION OF THE KARROO NORTH OF THE ZAMBEZI

BY

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In his valuable work on the Geology of South Africa DR. A. L. DU TOIT has given a most useful summary account of the Karroo System as far north as the Zambezi. The present paper is an attempt to continue the description so as to include the Karroo of Central and Eastern Africa as far north as the point at which the system comes to an end beneath the marine transgression of the early Jurassic. The account of the Karroo of Central Africa, which may be regarded as including Rhodesia, Nyasaland, and the immediately adjacent areas, is based partly upon recent observation by the writer combined with the determination of reptilian and other remains by DR. S. H. HAUGHTON and of fossil plants by MR. JOHN WALTON. Amongst the plants collected from the Lower Zambezi MR. WALTON has recognised *Rhexoxylon africanum*, which not only has proved most useful for purposes of correlation but is also of additional interest in that it constitutes only the third known occurrence of this form in Africa. The recognition of Lower Beaufort and other reptiles has also given valuable assistance. In the account of Eastern Africa, including Tanganyika, Kenya, Uganda, the upper Congo, Abyssinia and Somaliland, the attempt is made to apply these results to the elucidation of the Karroo as far as its northern limit.

The Karroo of Central Africa was laid down upon a very uneven floor; moreover, there is evidence to show that at least some of the existing larger outcrops mark the sites of more or less isolated areas of deposition. Just as the northern region was separated from the main Karroo area of the south by the great pre-Karroo ridge of the Central Transvaal, so the Lower Shire —Zambezi area was partly cut off from the Upper Zambezi or Wankie area by the Rhodesian highveld, upon the crystalline rocks of which uppermost Karroo beds now rest. The Upper Karroo and the basalt of the Kafue River (XIV)[1]. similarly lie upon a ridge that divided the Wankie area from the Luano at the southern end of the Luangwa Valley; while the westward

[1]) Numbers in brackets refer to the bibliography at the end

thinning-out of the Lower Sandstone (Middle Ecca) of the North Nyasa area (I) and the presence of mudstones of Lower Beaufort age on the Angoniland crystalline plateau (V (3)) suggest that a pre-Karroo upland lay between the North Nyasa and upper Luangwa areas. Similarly a steep ridge of at least local importance bounded the Lower Shire area on the east, for within a few miles the whole of the Lower Sandstone normally about 4,000 feet thick, is cut out by the overlap of the Coal Shale Group (Upper Ecca) on to beds of the Nachipere Series on the Port Herald Hills (V (10), 1928). On the western side about 10 miles E.N.E. of Tete in the bed of the Moatize River, a tributary of the Revugo, the coal shales again rest locally on the crystalline rocks.

In view of these more or less isolated major basins of deposition of the Karroo it is not surprising that there should be difficulties in the way of complete correlation, but in spite of this it is possible to recognise at least the larger Karroo sub-divisions in the northern areas.

The Karroo attains its maximum development of 26,800 feet in Cape Province, and northwards it dwindles to 2,430 feet in the Central Transvaal; it increases to 3.770 feet on the Upper Zambezi, and this increase is maintained north-eastwards to about 4,200 feet in North Nyasa.

But the total thickness of the Karroo of the Lower Zambezi, namely 18,000 feet, is much greater than that of any of the other known Central African areas, and in this respect, as well as in the thickness of the individual major zones, the succession corresponds more closely to that of Cape Province. An additional correspondence is seen in the thickness of the lavas, which amounts to 4,500 feet. The only other area in which the development of the lavas approaches or exceeds this amount is the intervening Lebombo belt, where the flows appear to be of enormous total thickness, since they dip steadily eastwards at angles of 10° to 15° for many miles. The Lower Zambezi lavas are further related to those of the Lebombo area in that towards the top they include thick flows of rhyolite. If a maximum outpouring of lavas be assumed to be connected with a preceding maximum downward movement leading to a vast accumulation of sediment, as appears to have been the case in Cape Province and the Lower Zambezi, then it is reasonable to suppose that these three areas were intimately connected with a principal region of Karroo deposition that extended around the eastern margin of what is now the African continent. Still farther north, in the coastal region near Tanga in Tanganyika Territory, there is a similar region of excessive deposition in which only a part of the beds that may be assigned to the Karroo are estimated as being at least 10,000 feet. Further reference to these beds is made in a later paragraph.

It is important to observe that while the whole of the Beaufort Series is missing from the Central Transvaal, Beaufort Beds re-appear in the northern region. The recent discovery of reptilian remains has proved that

the Lower Beaufort is certainly present in North Nyasa (V (3), IX (3)) and the Upper Luangwa (V (8)), and a comparison of the areas now under review not only tends to confirm DU TOIT's suggestion (VI (1), p. 254) that in the Upper Zambesi a stratigraphical gap exists at the top of the Beaufort, but also indicates that this gap represents the whole of the Middle and Upper Beaufort and probably extends throughout Central Africa at least. This view as to the magnitude of the break receives support from a comparison of the development of the major Karroo divisions in Cape Province and the Lower Zambezi; the thickness of the Ecca and the Stormberg in the Lower Zambezi is comparable with that of Cape Province, whereas the Beaufort beds recognised altogether amount to no more than 3,000 feet as compared with 6,000 feet for the Lower Beaufort alone in the southern area; it would therefore appear that merely a small part of the Beaufort is represented, and the available stratigraphical and palaeontological evidence indicates that this part comprises only the Lower Beaufort.

It is possible that this stratigraphical break may throw some light on the interesting occurrence of fossil plants of European affinities in the Tanga area in Tanganyika Territory (XVII). Here there is a great accumulation of sediments of Karroo age not parallelled elsewhere in Eastern Africa; the Lower Tanga Beds are considered to be the equivalent of the Taru Grits and of the Sabaki shales in which occurs the Permian mollusc *Palaeanodonta fischeri*. The Middle Tanga Beds contain the fossil plants referred to which are regarded by PROFESSOR SEWARD as indicating an age between the Upper Permian and the Rhaetic, probably Trias. Since *Palaeanodonta* occurs elsewhere in Eastern and Central Africa in beds considered to be of Lower Beaufort age, and since no break has been observed in the Tanga succession, it is reasonable to regard the Tanga Beds as being probably Middle and Upper Beaufort and Lower Stormberg; for beds presumably younger than the Upper Tanga Beds, namely the Shimba Grits, are known to be of desert origin and would therefore appear to be of Upper Stormberg age (see below, p. 153.)

In view of these considerations it is reasonable to suppose that the widespread uplift responsible for the absence of the Middle and Upper Beaufort elsewhere in Eastern Africa, as well as in Central Africa and the northern part of South Africa, was accompanied in the Tanga area by a complementary depression that enabled deposition to continue at an increased rate and gave access to the European flora. Subsequently, in the Lower Stormberg, normal Karroo conditions returned to the area.

The available evidence suggests that the Stormberg lavas can be traced northwards from the Zambezi into Somaliland. But throughout this northern area it appears that the lavas, although forming large sheets in some places, were not continuous as in South Africa or Southern Rhodesia, but were due to isolated outbursts, for locally the desert beds of presumed Upper

Stormberg age are free from immediately overlying flows, as in the Upper Luangwa and in the Tanga area. Moreover, these northern outbursts resemble those of the Lower Zambezi and the Lebombo Mountains in that acid lavas or tuffs were intercalated amongst the basic rocks. It is possible that the presence of the acid rocks bears some relation to the sporadic nature of the outbursts.

Central Africa.

The following account will deal principally with the Karroo of the Upper Zambezi, the Lower Zambezi (i.e. the Lower Shire—Zambezi area), the south-western part of North-Eastern Rhodesia, the Upper Luangwa Valley, and the country around the northern end of Lake Nyasa; the succession in these different areas is given in the accompanying table A, and it will be seen that a very satisfactory correlation can be made out based both on stratigraphical and on palaeontological evidence.

The Dwyka is only doubtfully present in Central Africa, and the Ecca is somewhat patchy in distribution owing to the irregularities in the pre-Karroo land surface. But the Lower Beaufort is well represented and the similarity in lithological character and the forms of life recorded point to uniformity of conditions over a very wide area; for example, the Luano Lower Beaufort fauna extends as far west as the Belgian Congo and as far east of Madagascar (VIII (2), p. 860), and the characters of the enclosing sediments have much in common. Subsequently these tranquil conditions were interrupted by widespread movements followed by the Stormberg transgression, and approximately uniform conditions did not return to the area until towards the end of the Stormberg, when æolian deposition under a desert climate brought sedimentation to an end. Irregular conditions again developed during the period of the Stormberg eruptions, for the resulting accumulations of basalt and rhyolite lavas appear to have been the products of merely local outbursts.

Ecca Series.

In all parts of Central Africa the Ecca Series where present has been found to rest directly upon pre-Karroo rocks without the intervention of any representative of the Dwyka Series. This series is nonetheless believed to occur in the Belgian Congo. (See p. 155.)

In general the deposition of the Ecca begin with a thick series of greyish sandstones and grits, with coarse basal conglomerates, which is assigned to the Middle Ecca. But beneath the Lower Sandstone (? 4,000 feet) of the Sumbu area of the Lower Zambezi is a group of green and red marls and sandstones, with thin-bedded soft white and pink sandstones, which appears to be comparable with the Lower Ecca shales of Cape Province (VI (1), p. 217) and of South West Africa (VI (1), p. 433.) On

the basis of fossil plants from the Lower and the Upper Zambezi, and North Nyasa, the coal-bearing shale group is considered to be of Upper Ecca age (I, VI, II.)

The lower sandstone series varies in thickness from 200 feet at Wankie to about 4000 feet in the Lower Zambezi, although locally as in the Port Herald Hills and the western part of North Nyasa it is overlapped by the shale group. It sometimes contains insignificant carbonaceous bands, and in the Mount Waller area of North Nyasa it includes 4 thin coal seams of poor quality (XI3.) In the Lower Zambezi area near Sumbu (V (1)) it is preceded by the red and green shales and sandstones already mentioned.

The coal-bearing group varies in thickness from about 200 feet at Wankie to fully 3,000 feet on the Lower Zambezi; in the latter area it is divided by a series of fine to medium-grained sandstones — the Tapasa Sandstone or *Grès de Matinte* — some hundreds of feet in thickness. In general it is not sharply marked off from the overlying sandstones, but passes up into them by alternation of argillaceous, sandy, and sometimes calcareous beds.

Beaufort Series.

The coal-bearing group is everywhere succeeded by sandstones and grits; these attain a maximum thickness of 1,500 feet in the Sumbu area of the Lower Zambezi, and in North Nyasa they are locally as much as 1,000 feet. In the Luano area of North-Eastern Rhodesia, where they form the lower part of the thick Upper Matabola Beds, they are finer-grained and less resistant than elsewhere, and they contain beds of blue-grey unstratified clays and a few bands of limestone. In North Nyasa and the Upper Luangwa Valley, they include a lower series of massive, current-bedded grey sandstones and grits, with thin pebble-beds, and an upper series of thick-bedded purplish grits and sandstones with a few interbedded purplish and green shales, mudstones, and limestones. In the Lower Zambezi they consist mainly of a monotonous succession of coarse greyish grits, often massive or current-bedded and locally pebbly, but at the base they include a transitional zone of alternating red and green mudstones, friable sandstones, and shales. These transitional beds are locally gypsiferous. Fragments of fossil wood are occasionally seen in the main sandstone and grit series.

The sandstone everywhere passes upwards into a group of pre-eminently soft argillaceous and calcareous strata known in Rhodesia as the Madumabisa Shales and the Upper Matabola Beds; these are essentially shallow-water sediments and in several areas they show sun-cracks and ripple marks. They generally yield fragments of fossil wood. In North Nyasa and the Upper Luangwa Valley they consist in the lower part of a thick series of greenish and greyish mudstones, argillaceous sandstones, and limestones, and in the upper part of reddish and purplish marls and mudstones, that

locally are calcareous or pebbly; the upper beds of these two areas have yielded abundant reptilian remains of Lower Beaufort age, and similar remains have been found also near the top of the Green Marls of the Upper Luangwa Valley. In two parts of the North Nyasa area the greyish calcareous beds have yielded *Palaeomutela oblonga, Estheriella,* and scales of *Colobodus Africanus* and *Acrolepis* sp. — a fauna similar to that of the Upper Matabola Beds, in which reptilian bone fragments are also known to occur.

In the Lower Shire area of the Lower Zambezi the series, termed the Red Marls, comprises principally a group of non-resistant pebbly marls and sandstones; grey and pink calcareous concretions are frequently associated with the marls, and pale grey limestones and greenish and buff-coloured calcareous shales occur at several horizons. A few resistant beds of grit and quartzite are also known. The marls are dominantly red in colour, but locally they are purplish, green, or mottled green and red. Green and buff calcareous and sandy shales have yielded plant fragments, fish scales, *Palaeanodonta* sp., *Cyzicus* (*Estheria*) cf. *Minuta,* and ostracods, and similar beds in the *Schistes de Mpiusa* (II), in part equivalent to and apparently continuous with the Red Marl series, have yielded *Vertebraria* sp. and *Glossopteris indica.*

The Red Marl series is directly overlain by strata carrying *Rheoxylom africanum,* an important Molteno form, and accordingly the Middle and Upper Beaufort is absent from the Lower Zambezi.

On lithological and stratigraphical grounds also there is good reason to believe that the series of mudstones, shales, and calcareous rocks from the different parts of Central Africa now under consideration are all essentially of the same age. On palaeontological grounds the Madamabisa Shales, the Upper Matabola Beds and the Drummond Beds of the North Nyasa calcareous series have long been held to be essentially equivalent, and to these the Red Marls of the Lower Zambezi may now be added; for although the molluscs and the crustaceans do not appear to be specifically similar the general character of the Lower Zambezi fauna and the lithological correspondence of the beds give ample support to this view. Furthermore, the Lower Zambezi beds contain the Lower Beaufort plants *Vertebraria* sp. and *Glossopteris indica.* The Green Mudstones of the Upper Luangwa have not yet yielded similar fossils, but the relation of these beds to the calcareous facies of the North Nyasa area leaves no reasonable room for doubt as to their equivalence.

The exact correlation of these beds with the South African Karroo has nonetheless been a question of some difficulty in the past; DU TOIT (VI (1), p. 245) regards them as certainly Beaufort, but considers it just possible that a gap exists at the top of the division. But the recent discovery of reptilian remains in the immediately succeeding beds at Chiweta in North

Nyasa and near Chikonta in the Upper Luangwa Valley places the matter beyond doubt; these upper beds belong to the *Endothiodon* and *Cistecephalus* zones of the Lower Beaufort, and accordingly the beds in question may now also be safely assigned to this stage.

These Lower Beaufort Beds of Central Africa are everywhere immediately followed by beds regarded as equivalent to the Escarpment Grits, which are themselves considered to be of Stormberg age; there is thus an important gap in the succession, and this may almost certainly be assigned to the effect of the Upper Karroo transgression by which the whole of the Beaufort was cut out from the northern Transvaal. More direct evidence for the northern discordance is seen in the Mafungabusi district of Southern Rhodesia, where the Escarpment Grits gradually step across the Upper Matabola Beds until finally they rest directly on the Archaean. This transgression was doubtless an effect of the intense compressive movements that began in South Africa towards the end of the Lower Beaufort and continued until the early Stormberg, when deposition re-commenced and gradually extended across the worn edges of the older beds.

Stormberg Series.

The Molteno Beds and Red Beds. The Lower Beaufort is everywhere followed by coarse grits that mark a sudden change in the character of the deposits; in consequence of their greater resistance to erosion these grits almost invariably give rise to a pronounced rocky scarp, and in Rhodesia they are on this account known as the Escarpment Grits.

In the Upper Zambezi and the Luano Valley the Escarpment Grits comprise strikingly red or brown (occasionally greyish), coarse, current-bedded grits containing banks of sub-angular pebbles, while they carry pellets of clay and are in places ferruginous. Intercalated hard, red, and sometimes calcareous clays have also been observed. At the upper end of the Luangwa Valley similar rocks occur at the corresponding horizon, and the Chiweta succession suddenly gives place to series of thick-bedded grits that may in all probability be correlated with these beds.

In the Lower Zambezi similar conditions prevail, and the scarp of these rocks is particularly well developed south-west of Mbuzi on the Nkombedzi wa Fodya River and west of Zimbawe; here, in common with the greater part of the Lower Zambezi succession, the beds are of great thickness namely 3,000 feet, as compared with 300 feet in Rhodesia.

These considerations indicate the general equivalence of the beds in the different areas, and this is confirmed in the case of the Lower and the Upper Zambezi by the discovery of fossil plants.

The Somabula Beds, themselves considered to be equivalent to the Escarpment Grits, have yielded *Thinnfeldia Feistmanteli*, ? *Thinnfeldia*

odontopteroides, *Schizoneura gondwanensis*, *Taeniopteris McClellandi*, *Rheoxoxylon africanum*, and *Dadoxylon* sp., and WALTON (XXII (1)) regards this flora as indicating equivalence to some part of the Stormberg Series about the horizon of the Red Beds of the Molteno Beds.

Rhexoxylon africanum has now been found in the Lower Zambezi at several points along the lower part as well as in the upper part of the Upper Sandstone, which is thereby shown to represent both the Somabula Beds and the Molteno Beds. The Red Beds would appear to be represented lithologically by red sandy marls that intervene between the Upper Sandstone and the Red Sandstones of both the Lower Zambezi and the Upper Luangwa, and by the intercalations of red marl in upper part of the Escarpment Grit.

But the Lower Zambezi beds are 3,000 feet thick whereas those of Somabula are only 180 feet: near the Kafue River only about 100 feet of these beds are present. While this is evidently due partly to normal thinning out as the beds approach the Rhodesian pre-Karroo ridge, it is probably mainly due to successive overlap of a large part of the Molteno Beds. A close parallel may be seen farther south where the Molteno Beds, 2,000 feet thick, are gradually cut out near Harrismith until the Red Beds, reduced from 1,600 feet to 300 feet, come to rest on the Upper Beaufort. Farther north the Red Beds are known as the Bushveld Marls, which appear to represent part of the Somabula Beds of Rhodesia.

Just as the thickness of the Upper Sandstone of the Lower Zambezi is comparable with that of the combined thickness of the Molteno and the Red Beds of Cape Province, so lithologically a large part of the Upper Sandstone much resembles the Molteno Beds. The Upper Sandstone consists almost wholly of thick-bedded coarse, sometimes pebbly, greyish grits and sandstones in which current-bedding is generally well developed. While no trace of the grey and blue shales and the coals of Cape Province have been observed, argillaceous bands, usually of a reddish colour, sometimes appear in the lower and the upper part of the series.

Cave Sandstone. In the Lower Zambezi and the Upper Luangwa Valley the Escarpment Grits and corresponding beds pass upwards without obvious break into soft reddish sandstones equivalent to the Forest Sandstone, which is held to represent the Cave Sandstone of Cape Province; but in Southern Rhodesia the lithological change is in general more clearly marked. Moreover, although the typical Forest Sandstone in Rhodesia is an even-grained deposit reminiscent of the Cape Sandstone, in other areas it and the corresponding beds tend to show some variation towards marly and pebbly facies. This is particularly the case in the Lower Zambezi, where the beds have nonetheless yielded dinosaurian bones that DR. HAUGHTON regards as representing the Upper Stormberg of South Africa; similar remains are known from the top of the Forest Sandstone of Southern Rhodesia.

The Forest Sandstone in Rhodesia attains a thickness of 210 feet; it immediately underlies the basalt and consists of white, buff, and reddish massive and fine-grained sandstone. The sand grains are often well-rounded, and irregular secondary silicification is frequently present. False-bedding occurs, and the sandstone tends to weather unevenly. Calcareous concretions are seen locally towards the base, and bands of sandy marl are sometimes intercalated in the sandstones. Pebbles are but rarely observed.

In the Upper Luangwa Valley (V (8)) the Red Sandstone comprises principally soft friable fine-grained sandstones of a predominantly reddish colour; in good sections thin white pink and mauve bands are seen to be interlaminated with the red sandstones, and current-bedding is also developed. Pebbles are generally absent, and pellets of red marl are sometimes seen in the sandstone. Quartzites occur at several horizons and generally give rise to scarps; they are variably granular, compact, or vitreous in appearance, and the colour is usually pale grey to buff.

In the Lower Zambezi (V (7)) where the beds of desert origin vary from 150 to 750 feet in thickness, two facies are present. The one, of smaller thickness, is mainly quartzitic and is well exposed at Chirunda Hill and Panga Hill; the beds contain well-rounded grains, and certain of the quartzites are of the compact, pale, buff-coloured type seen in Rhodesia and the Upper Luangwa Valley, as well as south of the Lower Zambezi near the Rhodesia border, (XIV). The second facies, which appears to be mainly a lateral variation of the first, is immediately overlain by the basalt to the south of Chirunda Hill; it ranges up to 750 feet in thickness and in general character resembles the Forest Sandstone of Rhodesia and the Luangwa Valley, except that it is thicker, better stratified, and more pebbly; for example, the bed immediately underlying the basalt along part of the outcrop is a coarse grey grit with a maximum observed thickness of 140 feet. Near Chimpundu these beds have yielded Upper Karroo dinosaurian remains. Desert sandstones are interbedded with the first few flows of basalt.

The Volcanic Rocks. Basalt lavas overlie the Upper Karroo rocks on the Lower and the Upper Zambezi, and on the Kafue River. On the Lower Zambezi they are 3,000 feet thick, exclusive of 600 feet of rhyolitic rocks intercalated between the basalts near the top of the sequence; these lavas are separated from the overlying Lower Lupata Sandstones, probably of early Cretaceous age (V (9), XIV), by a strong unconformity. In Southern Rhodesia the basalts are considered to be about 2,000 feet thick, and on the Kafue River about 600 feet. Apart from the basalts overlying the Lualaba Beds of the Belgian Congo, which are believed to be of Karroo age and lie between $0\frac{1}{4}°$ and $9\frac{3}{4}°$ S. lat, the Kafue flows mark the northern limit of the Karroo basalts of Central Africa. Nevertheless, in the Karroo of the Mount Waller area in North Nyasa, and in the crystalline rocks intervening

between North Nyasa and the Upper Luangwa Valley, there are fresh doleritic intrusions in no way distinguishable from those in the Karroo of the Lower Zambezi; moreover, Studt. (XIX, p. 59) has recorded basalt lavas from Sumbu at the southern end of Lake Tanganyika 300 miles to the north-west.

Eastern Africa.

Tanganyika and Kenya. Karroo beds are known from 8 areas in Tanganyika, and of these the most important are Ruhuhu, Kivira — Songwe, Kigoma, Rufiji, Kidodi, and Tanga. Fossil plants show that the Ecca is represented in several of these areas. The upper beds of the Karroo, except in the Tanga area, are often vividly coloured in red, green, and violet, and also calcareous rocks are abundantly developed in them (XII, p. 298.) These characters accord well with those of the Lower Beaufort of North Nyasa and the Upper Luangwa Valley, and the suggestion as to the general equivalence of the beds is supported by palaeontological evidence.

The Karroo of the Ruhuhu and the Kivira-Songwe areas near the northern end of Lake Nyasa is much like that of the Songwe and of Mount Waller in the neighbouring parts of Nyasaland, and a comparison leads to the conclusion that the Middle and Upper Ecca and the Lower Beaufort are similarly represented in the Tanganyika outcrops.

In the area east of Kigoma on Lake Tanganyika Karroo sediments have recently been recognised amongst the "Tanganyika Sandstones." Teale and Gillman (XX (2)) have shown that certain beds comprise plant-bearing shales identical in character with the Karroo beds in other parts of the Territory, but even before these observations were made Krenkel had regarded the "Tanganyika Sandstones" as being in part of Karroo age. Above the plant-bearing beds is a thick series of limestones and mudstones similar to the Lower Beaufort beds of the Kivira-Songwe area; these are traversed by dolerite and are overlain by amygdaloidal diabase and associated acid tuffs that are probably to be correlated with the Stormberg volcanic rocks of the Lower Zambezi.

According to Fourmarier (VIII (1)), a glacial conglomerate resting on a striated pavement underlies the carbonaceous beds of the Lukuga Valley on the western side of Lake Tanganyika.

In the Rufiji area in the eastern part of the Territory coalbearing beds yielding *Glossopteris* and other plants are assigned to the Ecca. In the Kidodi area a few miles to the west, where the Karroo attains a thickness of nearly 3,000 feet, similar beds are followed by calcareous and argillaceous strata yielding *Colobodus africanus* and a number of fresh water shells that include *Palaeanodonta okensis* and several species of *Palaeomutela*, particularly *P. oblonga*. *Colobodus africanus* and *P. oblonga* are already known from similar beds in two of the Lower Beaufort areas of North

Nyasa, and the Kidodi beds would accordingly appear to be equivalent to these. It is of interest also that the Kidodi beds contain a 3-foot seam of impure coal (XII, p. 300) which is comparable with the coal seams of the corresponding beds of North Nyasa.

The Tanga Beds. A series of sediments known as the Tanga beds extends northwards of Tanga along the coastal belt. The beds, which exceed 10,000 feet in thickness, are considered to be of Karroo age, although the plants they yield are of European rather than South African affinities; no *Glossopteris* has been found in them. The sediments fall roughly into three divisions, a lower, middle, and an upper group. In the lower division conglomerates, arkose, and felspathic sandstones predominate, but numerous bands of dark carbonaceous shale are present; these beds probably correspond to the Taru Grits of Kenya Colony. No identifiable plant remains have been obtained from this group.

The middle division contains dark carbonaceous shales and flagstones with abundant plant remains. The plants are poorly preserved, but *Ullmania* sp. and *Voltzia* sp. have been recognised by PROFESSOR A. C. SEWARD, who considers that they indicate an age between the Upper Permian and the Rhaetic, probably Trias (IX (2), p. 84.)

The upper division consists of irregularly-bedded sandstones alternating with lighter coloured somewhat sandy shales. According to DR. E. O. TEALE (XVII, p. 387) this group probably includes representatives of the remaining upper portion of the Duruma Sandstone of Kenya, such as the Mariakani and Mazeras Sandstones and the Shimba Grits; but PROFESSOR J. W. GREGORY (IX (2), p. 85) considers that the Mazeras Sandstone and the Shimba Grits may be younger than the Tanga beds.

Similar fossils have since been recorded by GREGORY (IX), from the upper part of the Taru Grits lying inland of Mombasa on the Uganda Railway; the name Samburu Grits is suggested for these upper beds, which are considered to correspond to the Middle Tanga beds.

If the Triassic age of the Middle Tanga beds be accepted, they would appear to have been laid down in part at least during the Middle and Upper Beaufort, particularly since the Sabaki shales, continuous with the Taru Grits and regarded as a northern extension of the Lower Tanga beds, have yielded the Volga Permian mollusc *Palaeanodonta fischeri; Palaeanodonta spp.* and the closely related form *Palaeomutela* occur elsewhere in Tanganyika in beds closely comparable with the Lower Beaufort of Nyasaland.

The tentative correlation of the Tanga sediments shown in Table B is accordingly suggested, and the Lower Shire — Zambezi succession is added for comparison.

If this correlation be accepted it would appear that the movements that elsewhere in Tanganyika and Central Africa resulted in the non-deposition

or erosion of the Middle and Upper Beaufort were accompanied in the Tanga area by a complementary depression that enabled continuous deposition to take place and admitted the flora of European affinities. This view is supported by the great thickness of the Tanga sediments, a thickness that is apparently not parallelled elsewhere in this part of Africa except in the Lower Zambezi, where the succession is closely related to that of Cape Province.

The salient features in the comparison of the Tanga sequence with that of the Lower Zambezi are as follows:—

(a) In both areas the succession ends with a series of sandstones including beds of desert origin; those of the Lower Zambezi are definitely of Upper Stormberg age.

(b) In both areas these upper sandstones are underlain by a thick series of grits and sandstones that include a well-marked horizon characterised by silicified tree-trunks referred to *Dadoxylon*. In the Lower Zambezi area this genus is accompanied by *Rhexoxylon africanum*, which indicates a lower Stormberg age.

(c) In both areas argillaceous beds appear below the sandstones of (b.)

(d) The fauna of the Lower Tanga beds bears some resemblance to that of the Lower Zambezi Red Marls, and in both areas there are horizons rich in indeterminable leaf fragments. The recognition of *Palaeanodonta fischeri* determines a Permian age for the Lower Tanga beds. The Lower Zambezi fauna, with *Palaeanodonta* spp., *Cyzicus* cf. *minuta*, and fish scales, is not of itself sufficiently definite to fix the age of the beds as Lower Beaufort, but the requisite proof is afforded by the presence of *Vertebraria* and *Glossopteris indica*, both unknown in South Africa above the Lower Beaufort (VI (1), p. 274), in the *Schistes de Mpiusa* (II, p. 763, XI, p. 8), which are equivalent to and apparently continuous with the plant and lamellibranch beds of the Red Marl series. This conclusion is supported by comparison of the fauna and the stratigraphical relations of this series with those of the Lower Beaufort of other parts of Central Africa. Apart from the Stormberg dinosaurs of the Lower Zambezi the only reptilian remains so far recovered from the two areas now considered are those described as *Tangasaurus mennelli*, which came from the lower part of the Tanga succession and are referred by Haughton (X (2), p. xxv) provisionally to the upper Permian or early Trias; this finding is consistent with the classification now proposed. It should be noted also that although carbonaceous beds appear to be almost unrepresented in the Red Marl series of the Lower Zambezi, thin coal seams are recorded from the corresponding beds of North Nyasa

and of Kidodi in Tanganyika. In view of these considerations the Lower Tanga beds and the Red Marl series may be regarded as essentially equivalent.

(e) The thickness of the corresponding sediments in the two areas are comparable.

Accordingly, the correspondence between the two areas is remarkably complete, provided the view as to the equivalence of the Middle Tanga stage with the Lower Zambezi unconformity is justified. From this it would appear that normal Karroo conditions returned to the Tanga area at about the beginning of the Stormberg; they continued during the deposition of the Middle and Upper Duruma Sandstone and culminated in the accumulation of the Shimba Grits under desert conditions. Whether or not any part of the Ecca is represented at Tanga remains doubtful in the absence of satisfactory palaeontological evidence; but an Ecca flora has been proved from Entebbe in Uganda, 5° farther north.

These suggestions as to the relation of the Tanga sediments to the Karroo of the Lower Zambezi are fully in accord with TEALE's view (XVII) that the Tanga rocks represent a distinct and later basin than those with typical Lower Karroo characters farther to the south and south-west.

The Belgian Congo. The sediments of the Belgian Congo, comprising principally the Lualaba and the Lubilache Beds, appear to form much the largest known Karroo outcrop in Africa (VI, (2.)) The lowest Lualaba Beds consist of glacial deposits (XII, p. 46.) These are followed by coal-bearing strata presumably of Ecca age (XIX, p. 56.) The upper beds comprise clays, grits, sandstones, and limestones with a few fish and crustacean remains, e.g. *Pholidophorus* and *Estheriella*, and they may accordingly be referred provisionally to the Beaufort, possibly the upper part (VI (1), p. 282.) The Lubilache Beds cover a much larger area and in places overlap the Lualaba; they consist of reddish to white friable sandstones and conglomerates with some red shales containing *Estheria*. The sand grains are well rounded, and various forms of secondary silica are present. The beds are about 1,000 feet thick (XIX, p. 56.) The general appearance of the Lubilache Beds recalls the Forest Sandstone of Rhodesia, and this suggestion as to their age is supported by the manner in which they overlap the Lualaba Beds, much as the Rhodesian Stormberg overlaps the Lower Beaufort. Moreover, it is of interest to note, as has been pointed out by DU TOIT (VI (1), p. 403), that in them diamonds are reported to occur just as in the equivalent Somabula Beds. Both the Lualaba and the Lubilache Beds are cut by dolerite dykes and are overlain by basalts and by more acid flows (XIX, p. 59); these rocks are probably to be referred to the Stormberg volcanic period.

Uganda. The most northerly beds known definitely to be of Karroo age are the shales and mudstones underlying Entebbe, practically on the Equator; these beds have yielded an Ecca flora (XXIII, p. 8.)

Abyssinia and Somaliland. To the north and north-east of Kenya terrestrial Triassic rocks considered to represent the middle and upper Karroo are followed without apparent break by marine Jurassic sediments. This area is accordingly of great interest in connection with the present enquiry, since elsewhere throughout Africa the Karroo sediments, where overlain by younger rocks, are separated from them by an unconformity that increases in magnitude towards the south; for example, in the Juba Valley of Somaliland the marine Lias rests upon the terrestrial upper Trias. from Mombasa to Mozambique the base of the Mesozoic rocks rises from Bathonian to Lower Cretaceous, while in South Africa only the Cretaceous is seen in contact with the Karroo (IX (1), p. 370.) The northern area now considered may therefore be expected on more detailed examination to yield fairly accurate information as to the date when Karroo deposition in this part of Africa came to an end. Although any attempt to correlate these northern sediments with the southern Karroo must be largely conjectural in the present state of knowledge, it will nonetheless be of interest to consider what conclusions may provisionally be drawn.

In Abyssinia the Adigrat Sandstone considered to be of middle and upper Triassic age is followed by the Abai Beds, which effect a transition from the terrestrial Adigrat Sandstone to the marine Antalo Limestone; the age of the latter is probably mainly or entirely Bathonian according to GREGORY, (IX (1), p. 330) or Dogger according to KRENKEL (XII, p. 182), and the Abai Beds are referred to the Rhaetic or the Lias because of their intermediate position, or to the infra-Lias, by DOUVILLE (IX (1), p. 339), because of the included *Corbula*.

The lower Adigrat Sandstone is coal-bearing; the upper part consists mainly of white sandstones, although locally the beds are variously coloured or highly ferruginous. These sandstones are characterised by massive structure and the absence of clearly defined bedding (XII, p. 182); no fossils have been found in them. The Abai Beds consist of yellow limestones with layers of dolomite and gypsum; they have yielded the *Corbula* sp. already mentioned.

In the southern part of Somaliland the Adigrat Sandstone is followed by the Lugh Beds, which show a transition to shallow-water marine conditions. The Lugh Beds, which occur on the middle Juba between Lugh and Dolo, at about 4° N. lat., and westwards up the Daua Valley, are of wide extent; they consist of sandstones and variegated clays with layers of dolomite and gypsum, and accordingly they resemble the Abai Beds in general character. But the Lugh Beds, which have yielded *Colobodus*

cf. *maximus* and fossil shells resembling *Modiola minuta*, have been referred to the Upper Trias, and would in that case be slightly older. Nevertheless GREGORY (IX (1), p. 330) considers that these fossils afford no definite evidence of Triassic age; the beds may be Rhaetic or even Liassic, KRENKEL places the Lugh and the Abai Beds in the Rhaetic or Lias (XII, p. 189), and GREGORY records marine Lias with *Leda complanata* from the Daua Valley, part of the Dolo-Lugh outcrop, and Bajocian with *Thamnastraea* cf. *terquemi* from south-west of Lugh.

In the Lugh and the Abai and related Beds there is therefore definite evidence of the gradual and intermittent incursion of the early Jurassic sea over the Karroo land surface. KRENKEL (XII, p. 184) considers that the marine incursion began in the Upper Trias, and HENNING regarded the Lugh Beds as indicating the path by which the Triassic sea reached the Congo Basin, where Triassic sediments, including the Lubilache Beds, extend over a very large area. But GREGORY (IX (1), p. 316) considers it is not yet proved that the Triassic sea reached East or Central Africa, for the marine fossil identified from the Juba Trias is doubtful, and there is no evidence that the Triassic beds east of Abyssinia are really marine; indeed the lithological nature of the Lubilache Beds, which extend northwards along the Upper Congo from Northern Rhodesia to the latitude of southern Abyssinia, immediately suggests correlation with the Forest Sandstone and Escarpment Grits of Rhodesia and with the Stormberg Beds of South Africa (X (1), p. 464; VI (1), p. 282.)

Probably the most satisfactory indication of the relation of the Karroo of Abyssinia and Somaliland to that of South Africa is to be obtained from consideration of the nature of the uppermost Karroo of these northern areas and of the volcanic rocks associated with them.

Basalts, and also rhyolitic rocks, similar to those constituting the northernmost known Stormberg lavas are associated with and are believed to be contemporaneous with the late Triassic and immediately post-Triassic rocks of southern Somaliland.

Throughout the southern part of Italian Somaliland there extends a widespread sheet of basaltic lavas and acid tuffs that SREFANINI (XVIII) has described as belonging to the upper part of the Lugh Beds, which, as already noted, are generally accepted as being of Rhaetic or Liassic age. These eruptive rocks are exposed only in the banks of the Juba, near Lugh, where they occur in the upper part of the gypsiferous sandstones and never outcrop with the Jurassic beds; hence STEFANINI regards them as older than the Jurassic limestones. It should be mentioned also that pebbles of olivine-diabase occur within the Lugh Beds (J. W. GREGORY, IX (1), p. 315, quoting ANGELIS and MILLOSEVICH.)

The basic rock from Cuteta, near Lugh, is described as a compact labradorite-augite basalt, with a little olivine, magnetite and ilmenite. The

acid tuffs include rhyolitic (liparitic) and trachytic varietes with anorthoclase and aegirine-augite.

Both GREGORY (IX (1), p. 322) and KRENKEL (XII, p. 194) are inclined to doubt STEFANINI'S view as to the age of the lavas, and to consider them instead as being related to the post-Jurassic outbursts; this doubt arises from the apparent absence in this part of Africa of similar rocks older than the Cretaceous. But similar rocks are recorded from the Ogaden country several hundred miles to the north-north-east (IX (1), p. 321), while basalts and rhyolites of early Jurassic or pre-Jurassic age are known also from other parts of British Somaliland (VII, p. 17.)

But STEFANINI'S view now receives strong additional support from the recognition of interbedded basalts and rhyolitic rocks of Karroo age in the Lebombo Mountains of Swaziland, of similar rocks in the Lower Shire—Zambezi area, of basalts and acid lavas resting locally on the Lubilache Beds of the Belgian Congo and North Eastern Rhodesia (XIX, p. 59), and of pre-Cretaceous acid and basic lavas and ashes in south-western Tanganyika (XX (2.)) In the Iringa District of Tanganyika rhyolitic rocks cover at least 1,250 square miles and the basic probably 800 square miles. East of Lake Tanganyika there is a vast area of amygdaloidal diabase with associated acid tuffs; these rocks rest upon Karroo sediments and presumably represent the Stormberg lavas.

Finally, basic dykes traverse the older rocks of Kenya and Uganda (XVI (2.)) (PARKINSON, p. 104), and in Uganda similar rocks intersect the argillite series of Karroo age (U.G.S., 1920).

In view of these considerations it is not unreasonable to regard the Lugh volcanics as being of upper Karroo age. and probably this remark would apply also to the other Somaliland lavas referred to.

As regards the nature of the uppermost Karroo sediments of the northern areas it would appear from KRENKEL'S (XII, p. 182) description of the uppermost Adigrat sandstones that these beds at least were formed under desert conditions; moreover, the uppermost Triassic beds of the Congo are in part of desert origin. The Rhodesian Forest Sandstones are now known to extend as far north as the upper Luangwa Valley and in all probability are represented also in the widespread uppermost Triassic beds of the Congo Basin (VI (1), p. 282, and X (1), p. 464), while the Shimba Grits of Kenya, probably of late Triassic or Rhaetic age. contain wind-polished pebbles and beds of desert sandstone (IX (1), p. 48); these circumstances strongly suggest that the desert conditions of the upper Stormberg extended northwards as far as Abyssinia, and that they played some part in the formation of the upper Adigrat Sandstone. This would be in accordance with the known almost world-wide distribution of such conditions at the close of the Trias.

If this view as to the northward extension of the desert conditions of the Upper Karroo and of the succeeding volcanic episode be accepted, then

the upper Adigrat Sandstone and the lower Transition Beds are of upper Stormberg age, while the Lugh and the Ogaden Lavas, as well as the early Jurassic or pre-Jurassic lavas of British Somaliland, represent the Stormberg volcanics. This conclusion receives confirmation in that on palaeontological and stratigraphical grounds the Lugh Beds are considered to be of Rhaetic or of Liassic age, while the uppermost Stormberg sediments are held to belong to the Rhaetic or possibly the early post-Rhaetic; for example, HAUGHTON is of the opinion (X (1), p. 491) that Stormberg sedimentation ended in the Rhaetic, and WALTON (XXII (1)) considers that the Somabula Beds of Southern Rhodesia, equivalent to the Stormberg Series at about the horizon of the Red Beds or the Molteno Beds, should be placed not lower than the Rhaetic. DU TOIT (VI (1), p. 281) regards the age of the Stormberg lavas as of Rhaetic or at the latest of Liassic age. It is probable that a detailed study of the Lugh sequence would enable the date of the Stormberg volcanic episode to be determined within yet closer limits.

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19. A COMPARISON OF THE FOSSIL FLORAS OF AUSTRALIA WITH THOSE OF SOUTH AFRICA

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Any comparison of the fossil floras of South Africa with those of Australia must be confined, to a great extent, to the floras of the Karroo System in South Africa and its equivalents in Australia. Very little is known of any pre-Karroo flora in South Africa and, so far as at present known, the Cretaceous floras of the two regions have comparatively little in common.

The attempt here made to correlate the floras has for its basis the author's examination of various fossil floras in Australia during the past fifteen years, the results of which have been published chiefly in the publications of the Queensland Geological Survey, the Proceedings of the Linnean Society of New South Wales, and the Papers and Proceedings of the Royal Society of Tasmania. No attempt is made to list the numerous species which have been found on the different horizons, as such lists would lengthen this communication unnecessarily and their value in a general statement of correlation tends, to some extent, to obscure general conclusions. It may be stated that the author has recently prepared a short account of the various fossil floras in Australia for inclusion in Sir Edgeworth David's forthcoming work on the geology of Australia.

In the succession of the floras in the two continents there are two outstanding features which must surely be of the greatest value for the purpose of stratigraphical correlation, viz.: (1) the first appearance of the Glossopteris Flora and (2) the appearance of what DU TOIT has aptly called the "Thinnfeldia Flora." The importance of these features is emphasized by the fact that each of these two floras as developed in Australia bears a close similarity to the corresponding flora in South Africa. The Glossopteris Flora represents an assemblage of a comparatively small number of genera amongst which *Glossopteris* is predominent. The use of the name "Gangamopteris Flora," in place of the originally proposed name, is misleading, since *Gangamopteris* is the predominant genus in few of the beds in which this flora is developed, whereas *Glossopteris* is usually in great abundance.

Floras of Pre-Karroo Age.

So little material is available for a consideration of floras of pre-Karroo time in South Africa that there is not sufficient ground for suggesting their relations with any of the Devonian or Carboniferous floras of Australia. Du Toit (Geology of S. Africa, 1926, p. 198) has mentioned the specimens described as *Cyclostigma* from the Carboniferous of New South Wales and Queensland, and some of these may perhaps be compared with the *Bothrodendron* of the Witteberg Series, but at present too little is known of their true affinities.

Floras of Karroo Age.

Commencing with the Dwyka Series of the Karroo System and continuing throughout the whole of this System there is a remarkably close parallelism of the floras with those of Australia, and a comparison of the floral succession in the two regions should assist in the determination of the correct position of the beds in the Geological Record.

The Glossopteris Flora.

The Glossopteris Flora makes its first appearance in South Africa with the occurrence of *Gangamopteris cyclopteroides* in the Boulder beds of the Dwyka Series; in Australia the lowest horizon on which it is known is about 2000 feet above the base of the Lower Marine Series. In both areas this flora then continues to increase, apparently reaching its maximum development in the Lower Beaufort Series and Newcastle Series respectively. In South Africa it persists and is found sparingly mingled with the Thinnfeldia Flora as high as the Molteno beds which are regarded as being of Upper Triassic age. In Australia, on the other hand, *Glossopteris, Gangamopteris, Vertebraria* and *Noeggerathiopsis* are not found above the top of the Newcastle Series (Upper Coal Measures), and have not anywhere in that continent been discovered associated with the Thinnfeldia Flora.

The Glossopteris Flora in Australia.

In New South Wales the succession from Devonian to Jurassic is more complete and better known than in any other of the Australian States, and for that reason is most suitable for use in a correlation with any extra-Australian succession.

The Glossopteris Flora in New South Wales is separated from the earlier flora of the Kuttung Series by an absolute break, not one of the species known from the Kuttung Series occurring in association with the Glossopteris Flora. The advent of the Glossopteris Flora is heralded by the occurrence of *Gangamopteris* in association with marine fossils on a horizon in the Lower Marine Series about 2000 feet above its base. Near the very base of this Series there is a thickness of one hundred feet of sandstone containing plant remains, but those fragments which have been obtained have all proved to be undeterminable. It is, therefore, impossible to say definitely whether the plants on this horizon show affinities with the earlier Kuttung flora or with the Glossopteris Flora. The recent discovery of *Eurydesma hobartense* below this horizon, however, seems to support, as a reasonable conclusion, the suggestion that the flora of this sandstone will prove to have affinity with the Glossopteris Flora.

Gangamopteris is thus the first genus, so far as is now known, to appear in the Glossopteris Flora in Australia. In the Greta (Lower) Coal Measures, which succeed the Lower Marine Series conformably, other genera are found, including *Phyllotheca, Annularia, Glossopteris* and *Noeggerathiopsis;* it is believed that *Gangamopteris* reaches its maximum development in this lower series of Coal Measures, but it may be stated here that so little has been done towards a complete description and comparison of the floras of the Lower (Greta) Coal Measures and the Upper (Newcastle) Coal Measures, that it is not possible at the present time to distinguish accurately between the floras of the two series.

Only a few species have been recorded from the Greta Series, these belonging to the genera *Phyllotheca, Annularia, Glossopteris, Gangamopteris* and *Noeggerathiopsis,* of which *Glossopteris* is represented by the greatest number of species.

The flora from the Upper (Newcastle) Coal Measures is more extensive and represents a far wider range of plants than is yet known from the Lower Coal Measures. About twenty-five species have been recorded in New South Wales representing the following genera: *Phyllotheca, Annularia, Schizoneura, Sphenopteris, Glossopteris, Vertebraria, Gangamopteris, Noeggerathiopsis, Dadoxylon, Samaropsis, Carpolithes, Cordaicarpus, Brachyphyllum* and (?) *Caulopteris.* Of the species described from the Upper Coal Measures, the following also occur in the Lower Beaufort beds in South Africa: *Schizoneura gondwanensis, Sphenopteris alata, Glossopteris Browniana, G. indica, G. angustifolia, G. conspicua, Vertebraria australis* and *Dadoxylon Arberi.*

Additional species have been described from Queensland, but recent fieldwork by J. H. Reid in the State indicates some uncertainty in the division of the strata into equivalents of Lower and Upper Coal Measures

of New South Wales. It is therefore thought wisest at present not to consider the Queensland species.

In New South Wales the upper limit of the Upper Coal Measures is generally taken as the top of the highest coal seam. *Glossopteris* is not found above this level, but within a few feet above this seam a small flora, consisting of *Schizoneura australis* (=*gondwanensis*), *Taeniopteris* cf. *McClellandi*, *Ginkgo dilatata* var. *lata*, and *Rhipidopsis ginkgoides* var. *Sussmilchi*, has been described. This small assemblage of plants shows much closer affinity with the Glossopteris Flora below than with the flora found higher up, and possibly indicates that the junction between the Upper Coal Measures and the Narrabeen beds should be placed a few feet above the highest coal seam of the Upper Coal Measures.

The Glossopteris Flora in South Africa.

In South Africa *Gangamopteris* occurs as low as the Boulder beds of the Dwyka Series, whilst even lower, in the Lower Shales of the same Series, *Phyllotheca* has been doubtfully recorded. Above the Boulder beds, in the Upper Shales, *Lepidodendron australe* and *Dadoxylon* sp. are recorded, associated with marine beds containing *Eurydesma* and *Conularia;* and, higher still, in the "White band," *Glossopteris* sp. is recorded. The record of *Lepidodendron australe* from such a horizon is most surprising from an Australian point of view. In Australia, whilst there is considerable variation among specimens referred to *Lepidodendron australe,* there is little doubt that the species does not occur in rocks of age later than Devonian—a conclusion borne out by Walton's comparison of some Queensland specimens with Dawson's *Leptophloeum* from the Devonian of North America. The Australian horizons for this species are thus separated from those on which the Glossopteris Flora occurs by an extensive marine Carboniferous Series and an equally extensive freshwater Carboniferous Series, the latter being some 9,000 feet thick and containing two successive floras, both of which are typically Lower Carboniferous as judged by the standard of European floras. It, therefore, does not seem unreasonable to suggest that this record of the occurrence of *Lepidodendron australe* in the Glossopteris Flora should be re-examined most critically.

In the Ecca Series twenty-two species* described are distributed among the genera *Phyllotheca, Lepidodendron, Sigillaria, Gangamopteris, Glossopteris, Vertebraria, Sphenopteris, Neuropteridium, Cordaites, Psygmophyllum, Ottokaria, Cardiocarpus, Conites* and *Dadoxylon.*

The records of *Lepidodendron* and *Sigillaria* indicate the persistence, in

* For complete lists see Du Toit, Geol. S. Africa, 1926. p. 274.

South Africa, of some Carboniferous forms into rocks in which the Glossopteris Flora occurs.

The lower division of the Beaufort Series has eighteen species belonging to the genera *Phyllotheca, Schizoneura, Sphenophyllum, Glossopteris, Vertebraria, Sphenopteris, Taeniopteris, Dadoxylon* and *Spiroxylon.* A number of them also occur in the Newcastle Coal Measures in Australia as noted above.

The record of *Taeniopteris* (*Angiopteridium*) *spathulata* in this flora is another surprising one in comparison with its occurrence in Australia, where it is very abundant in the Jurassic Flora, but is not known in rocks older than Lower Jurassic.

The middle division of the Beaufort Series also has very occasional representatives of the Glossopteris Flora, but the upper division is characterized by the appearance of the typical Mesozoic Thinnfeldia Flora.

Correlation of Glossopteris Floras of South Africa and Australia.

The appearance of the Glossopteris Flora is an event of sufficient importance to justify its use as a horizon indicator. It is not to be expected that the pre-existing flora would have been completely exterminated before the initiation of the Glossopteris Flora, and therefore the presence of a few species of the earlier flora associated with the Glossopteris Flora should not be given undue weight in the determination of the age of the beds in which they occur. The first marked appearance of a flora (or fauna) is much more important in determination of age than the presence of the last lingering representatives of an earlier one.

From a consideration of the occurrence of the Glossopteris Flora, it seems to me that the Lower (Greta) Coal Measures of Australia should be correlated with the Middle Ecca Coal Measures of South Africa, and that the Upper (Newcastle) Coal Measures of Australia must be regarded as the equivalent of part of the Lower and Middle Beaufort Series. The first appearance of *Gangamopteris* in New South Wales is nearly 3,000 feet below the Greta Coal Measures, whereas in South Africa it appears in the Boulder Beds of the Dwyka Series, at least 3,500 feet below the Middle Ecca Coal Measures.

It is difficult to say what is the exact position of he Tomango and Dempsey Series of New South Wales in comparison with the South African succession, but it seems most probable that they may be correlated with portion of the Lower Beaufort Series.

From the evidence of the fossil plants there does not seem to be any justification for correlating the Middle Beaufort Series of South Africa with the Narrabeen beds of New South Wales. The following table shows the correlation indicated by the results of my work:

	Australia:	*South Africa*:
Triassic.	Wianamatta Beds.	Molteno Beds.
	Hawkesbury Sandstone Beds. Narrabeen Beds.	Upper Beaufort (Burghersdorp) Beds.
Permian.	Newcastle Coal Measures.	Middle Beaufort Beds.
	Dempsey Series. Tomango Series	Lower Beaufort Beds.
	Upper Marine Series.	Upper Ecca Beds.
	Greta Coal Measures.	Middle Ecca Beds.
	Lower Marine Series.	Lower Ecca Beds. Dwyka Series.
Carboniferous	Kuttung Series. Burindi Series.	Witteberg Series.

There has been considerable divergence of opinion as to the correlation of the Australian so-called "Permo-Carboniferous" System with the lower portions of the Karroo, and also regarding their actual position in the Geological Record. On the one hand, Du Toit (Geology of S. Africa) has correlated the Lower Marine Series and Greta Coal Measures with the Dwyka Series and placed them in the Upper Carboniferous, and on the other, Schuchert (Bull. Geol. Soc. Amer., 39, 1928 (1929, 798, 869) includes the Seaham Glacial Beds with the Lower Marine Series and Greta Coal Measures as equivalents of the Dwyka Series, placing them as Middle Permian.

Considering first Du Toit's correlation, it seems to me that the Greta Coal Measures would be more correctly placed as the equivalent of the Middle Ecca Coal Measures than of the 'white band' of the Upper Dwyka. In view of the facts that (1) it is almost impossible to distinguish between the marine faunas of the Lower Marine and Upper Marine Series in Australia, and (2) the floras of the Greta Coal Measures and Newcastle Coal Measures can hardly be distinguished from one another, it is very difficult to believe that all four Series do not belong to one geological system. I therefore regard them as of Permian age and suggest that the base of the Permian in Australia, is, as originally suggested by David, about the base of the Lochinvar beds in New South Wales.

In placing the Seaham Glacial beds with the Lower Marine Series, Schuchert is governed by his conception that "the late Palaeozoic glaciation took place certainly in Middle and probably in Late Middle Permian time........" (*l.c.*, p. 772). In applying this idea to Australia, however, he

has placed himself in a difficult position by his statement that "it is a foregone conclusion that this species (*Aneimites inequilaterus*) can not occur in the Seaham Series." The Rhacopteris flora does occur abundantly in the lower part of the Glacial Stage of the Kuttung Series and there is no reason why the record of its occurrence in the upper part of the same Stage should not be correct. A summary of the succession of the Kuttung Series, as prepared by G. D. OSBORNE, who has carried out very extensive field-work on the Series, is as follows:

Glacial Stage:
- Upper part: 1,900 feet.
- Paterson toscanite: 300 feet.
- Lower part: 2,000 feet.

Volcanic Stage: 3,000 feet.

Basal Stage: 2,300 feet.

I entirely agree with DAVID WHITE's statement, quoted by SCHUCHERT (*l.c.*, p. 874) that "There is really very slender excuse for the obvious blunder of putting the *Rhacopteris inequilatera* flora or any other Rhacopteris flora in the Permian." But this quotation reacts very strongly against SCHUCHERT's thesis that the late Palaeozoic glaciation was Middle Permian, as by this correlation SCHUCHERT himself is the only one, to the best of my knowledge, who has placed a Rhacopteris flora in the Permian. It would seem then that possibly the whole of SCHUCHERT's thesis must fall, for there is not the slightest doubt that a large portion of the late Palaeozoic glacial beds in New South Wales is of Carboniferous age, either Lower Carboniferous or low down in the Upper Carboniferous, as the Rhacopteris flora may have lingered into the Upper Carboniferous in this region. Between the Carboniferous (Burindi and Kuttung Series) and the succeeding Permian strata there is a very marked palaeontological break in Australia, none of the plants and practically none of the animals continuing upwards from the Carboniferous. No trace has yet been found of any Upper Carboniferous flora in Australia and there appears to be a distinct stratigraphical break representing perhaps the greater part of Upper Carboniferous time. It is possible, though at present apparently not capable of demonstration, that the glacial conditions, initiated in the Lower Carboniferous, continued through a considerable portion of the Upper Carboniferous and resulted in the exclusion of the Normal Upper Carboniferous flora from Australia, whereas, with the continuance of glacial conditions, the Rhacopteris flora persisted longer in Australia than elsewhere.

THE THINNFELDIA FLORA.

The name "Thinnfeldia Flora" has been suggested by DU TOIT for the characteristic Triassic flora of South Africa, South America and Australia in

which *Thinnfeldia* is the most striking and abundant genus.

In Australia this flora makes its first appearance in the Narrabeen Beds, the only survivor from the Glossopteris Flora being *Phyllotheca australis*. The Thinnfeldia Flora is quite abundant in the Narrabeen Beds. It is more sparingly developed in the succeeding Hawkesbury Sandstone Beds, but in the Wianamatta Beds and their equivalents in Eastern Australia the flora is known to be a very extensive one, more than a hundred species having been described. *Thinnfeldia* became practically extinct in Australia by the close of the Triassic.

In South Africa the Thinnfeldia Flora appeared first in the Upper Beaufort Series (Burghersdorp Beds) and became abundant near the top of the Series. It reached its greatest development in the succeeding Molteno Beds from which about sixty species have been recorded.

Correlation of the Thinnfeldia Floras of South Africa and Australia.

There is little room for difference of opinion regarding the correlation of the beds containing the Thinnfeldia Flora in South Africa and Australia. The first marked appearance of the flora in South Africa is in the Upper Beaufort (Burghersdorp) Beds and in Australia in the Narrabeen Beds, and no hesitation is felt in correlating these two. There does not seem to be sufficient ground for suggesting, as Du Toit does (Geol. S. Af., p. 277), that the Narrabeen Beds are the equivalent of the Middle Beaufort Beds rather than of the Upper Beaufort Beds. The flora of the Wianamatta Beds and their equivalents in Australia bears such a striking resemblance to that of the Molteno Beds that the correlation of these with one another has been generally accepted. The equivalents of the Wianamatta Beds in Australia include the Esk and Ipswich Series in Queensland, the Lower Mesozoic beds in Eastern Tasmania, the Triassic plant-bearing beds at Bacchus Marsh in Victoria, and those at Leigh Creek in South Australia.

Floras of Post-Triassic Age.

Jurassic. The Jurassic floras of Australia, which are of widespread occurrence, do not appear to be represented at all in South Africa.

Cretaceous.—There are distinct Cretaceous floras in Australia in the Maryborough Marine Series, the Burrum Coal Measures, the Styx Series. and in the Cape York Peninsula on the Pascoe River. The Cretaceous flora in South Africa, which has been referred to the Uitenhage, appears to have only a single species in common with any of these floras, but shows closest resemblance to the flora of the Burrum Series of Coal Measures, there being nine genera common to the two.

20. LE SYSTEME DU KARROO. au Congo Belge

par

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I. HISTORIQUE.

A la suite de son expédition au Katanga en 1891-1893, le savant géologue belge JULES CORNET proposa de rapporter au système du Karroo, la série la plus élevée des terrains sédimentaires connus dans l'intérieur du bassin du Congo (1).

Déjà en 1886 le Dr. PESCHUEL-LOESCHE ([2]) avait observé qu'à l'Est des terrains plissés et métamorphiques de la chaîne côtière bordant à l'Ouest la dépression congolaise, s'étendent des couches sensiblement horizontales appartenant à des formations plus récentes.

En 1888, EDOUARD DUPONT ([3]) reconnut dans ces couches horizontales deux groupes distincts: celui des grès rouges feldspathiques à la base et celui des grès blancs friables du Haut Congo, avec quartzites, au sommet.

A la suite de ses progres observations, JULES CORNET, maintint la distinction entre les terrains anciens qu'il rapportait au paléozoïque d'une part et les terrains "post primaires ([4]) sensiblement horizontaux, d'autre part. Dans la dépression centrale du Congo et à sa bordure, depuis le Bas-Congo jusqu'au Katanga, il confirma l'opinion de DUPONT sur la répartition de ces terrains "postprimaires" en deux systèmes auxquels il donne les noms suivants:

a) le système du Kundelungu à la base;
b) le système du Lubilache au sommet.

([1]) J. CORNETT. Les formation, postprimaires du bassin du Congo Ann Soc. Géol de Belgique t XXI. Mém. p. 193.

([2]) PESCHUEL LOESCHE Zur Geologie des westlichen Kongogebietes. Deutsche Rundschau für Geographie und Statistik, VIII No. 7, 1886.

([3]) ED. DUPONT. Lettres sur le Congo. Paris 1889.

([4]) J CORNET. Les formations postprimaires du Bassin du Congo Annales Société géologique de Belgique t. XXI. Mém. p. 193. 1894.

Dans sa remarquable étude de 1894, Cornet fait observer que les couches du Kundelungu ne sont pas strictement horizontales, mais sont souvent légèrement ondulées tandis que les couches du Lubilache n'ont qu'une inclinaison très faible "qui peut être originelle." Il observe aussi qu'en beaucoup d'endroits les couches du Kundelungu font défaut entre le système du Lubilache et le substratum primaire ou archéen. Il indique ainsi que la formation du Kundelungu a été soumise à une dénudation qui en a fait disparaitre une grande partie avant que se déposent les couches du Lubilache; même là où la formation existe, elle a subi les effets de l'érosion, car dans le Bas-Congo, par exemple, les couches supérieures de la série du plateau des Kundelungu et de la Manika fout défaut.

Dans ce même travail, J. Cornet discute la question de l'âge des systèmes du Kundelungu et du Lubilache, question difficile à résoudre car, à cette époque, aucune couche de cette grande série n'avait fournie de restes organiques. Les formations envisagées étaient regardées comme d'origine iacustre d'après leur disposition gœnérale et étant disposées à peu près horizontalement, il paraissait, pour le moins rationnel de les parallèliser à la Formation ou Système du Karroo de l'Afrique australe dont l'allure est également voisine de l'horizontale et dont l'origine lacustre est établie par la faune et la flore, la présence de couche de charbon etc.

Aussi, depuis les travaux de Cornet, était-il admis généralement que le Karroo est représenté au Congo Belge par le système du Kundelungu tel que l'entendait Cornet (système de la M'Pioka et de l'Inkissi du congo occidental ou "grès rouges" d'Edouard Dupont) et les couches du système du Lubilache.

A la suite des études de M. le Professeur Maurice Robert [5] dans la partie Nord du massif des Kundelungu, il fut établi qu'il existait en concordance sous la série du Kundelungu de Cornet, un ensemble de couches schisto-calcaires avec conglomérat glaciaire de base.

D'autre part, les observations détaillées effectuées au Katanga méridional, aux abords du plateau des Kundelungu et du plateau de la Makika, conduisirent à la conclusion que les couches sensiblement horizontales, ou plutôt ondulées du plateau des Kundelungu et du plateau de la Manika, passent progressivement aux couches plissées du Katanga méridional, que Cornet considérait comme un système antérieur séparé du précédent par une importante discordance de stratification; seule la formation du Lubilache est partout exempte de plissements et repose en discordance sur les terrains antérieurs.

Chose remarquable, les levés de détail exécutés dans le Congo occidental, à l'Ouest du Stanley-Pool, ont établi avec certitude que les systèmes de

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(5) M. Robert. Le système du Kundelungu au Katanga. Ann. Soc. Géol. de Belgique Publ. Spéc. relat. Congo Belge. Année 1912-1913.

la M'Pioka et de l'Inkissi, que Cornet assimilait à son système du Kundelungu au Katanga, ne sont pas discordants sur la série schisto-calcaire sous jacente, mais lui font suite en concordance de stratification ou tout au moins n'en sont séparés que par une lacune de minime importance et suivent leur allure [6].

Dans ces conditions, le système du Kundelungu de Cornet s'apparente aux formations sous jacentes et se sépare nettement du système du Lubilache.

La formation schiste-calcaire à laquelle se relient aini les couches M'Pioka-Inkissi du Congo occidental et les couches du plateau des Kundelungu au Katanga, se prolonge jusque dans l'afrique australe et appartient au système Nama-Transvaal bien antérieur au Karroo.

Pour ce qui concerne l'intérieur du Congo, il n'est donc plus possible de rapporter au Karroo l'ensemble des formations que Cornet y assimilait. Reste la question du Lubilache.

Au point de vue historique, il convient de rappeler ici que Cornet, en 1008 [7] a donné le nom de système du Lualaba à un ensemble de couches schisto-gréseuses avec calcaires subordonnés, qui dans la partie orientale et septentrionale de la grande cuvette centrale du Congo, viennent s'intercaler entre le substratum ancien et les grès du Lubilache qui les surmontent en concordance. Pendant quelque temps on a hésité sur le point de savoir si le système du Lualaba est un facies du système du Lubilache tel que Cornet l'avait défini dans le congo occidental et dans le bassin du Sankuru-Kasaï ou s'il constitue une formation sous-jacente.

Nous verrons tout à l'heure comment cette question doit être résolue. Pour le moment, il suffit de signaler que les couches du Lualaba ont fourni des fossiles qui ont permis de préciser leur âge rhétien; dans l'Est, les couches inférieures renfermant des couches de charbon ont donné des traces de *Vertebraria* (Glossopteris) elles peuvent donc être triasiques.

Dans la vallée de l'Inzia (affluent du Kasaï) on a trouvœ en plein dans la zone gréseuse que Cornet rapportait à son système du Lubilache, des fossiles analogues à ceux de son système du Lualaba. Enfin, beaucoup plus récemment, près de la frontirère de l'Angola, au sommet du Mont Bunza, on a rencontré une faune jurassique.

Il résulte de là que l'ensemble des couches désignées sous le nom de système du Lualaba-Lubilache appartient au triasique et au jurassique inférieur et la faune qui les caractérise est d'eau douce ou saumatre; on y trouve du charbon. On peut assimiler cet ensemble, discordant sur toutes les formetions antérieures, au système du Karroo de l'Africe Australe.

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(6) Von F. Delhaye et M. Sluys. Présentation d'une carte géologique originale du Congo occidental à l'échelle du 1:200.000, publiée sous le titre: Esquisse géologique du Congo occidental. Etude du système schisto calcaire: Soc. Géol. Belgique. Publ. Congo 1923-24.

(7) J. Cornét. Les couches du Lualaba. Ann. Soc. Géol. de Belgique t. XXXV. Bull p. 99.

S'il faut exclure du système du Karroo, les couches du Kundelungu de Cornet et les couches equivalentes, on peut se demander si en dehors du centre du pays, il n'y a pas d'autres terrains à rattacher au même système.

Dans la zone littorale à la base de la série horizontale se trouvent des grès connus sous le nom de "grès sublitto raux." D'après leurs caractères, certains auteurs ont pensé pouvoir les rattacher aussi au Karroo. Les recherches affectuées dans l'Angola portugais conduisent à penser qu'il faut les placer dans le crétacique.

Le système du Karroo n'est donc représenté au Congo que dans l'intérieur du continent à l'Est de la chaine qui limite vers Ouest la dépression centrale.

II. La Composition du Systeme du Karroo au Congo Belge.

Nous avons indiqué dans le paragraphe précédent quels sont les terrains sédimentaires du Congo Belge qui peuvent être assimilés au Karroo de l'afrique australe.

La limite inférieure de ces formations, comprenant les Systèmes du Lubilache er du Lualaba tels qu'ils ont été definis par J. Cornet est nettement marquée par la discordance de stratification séparant cet ensemble, des terrains sous-jacents.

La limite supérieure est plus difficile à établir. Dans le centre de la dépression du Congo, là où par suite de l'allure des couches, la formation semble devoir atteindre son maximum d'épaisseur, les grès du Lubilache sont recouverts par les dépots quaternaires ou modernes.

Cependant au sommet du Mont Bunza, un niveau fossilifère intéressant a été découvert il y a peu de temps ([8]) et permet de discuter de la limite supérieure.

Les roches fossilifères ont été trouvées à l'état de blocs amoncelés, où il n'est pas possible de voir la stratification et dont les relations avec les roches gréseuses du Lubilache, situées par dessous, ne peuvent être déterminées avec toute certitude.

La faune comprenant *Physa Parmentieri, Cypris Farnhami, Chara de Rauwi, Planorbis,* sp. correspond. d'après M. Leriche[9] au Jurassique et montre quelques affinités avec le Purbeckien d'Europe. La première opinion fut que l'on se trouvait en présence des couches les plus élevées du Karroo du Congo Belge et que celui-ci s'élevait au moins jusqu'au jurassique inférieur.

([8]) H. de Rauw. Contribution à la géologie du Sud du Kasaï. Ann. Soc. Géol. de Belg. Public spéc relat. Congo Belge 1926-27, p. 37.

([9]) M. Leriche. Les fossiles des "grès polymorphes." (couches du Lubilache) aux confins du Congo et de l'Angola. *Rev. Zool. Africaine.* Vol. XV. et *Ann. Soc. Géol. de Belg. Public spéc. relat. Congo* 1926-1927.

Cependant M. MAUFE, le savant directeur du geological survey of Southerh Rhodésia, a présenté tout rémment une note ([10]) dans laquelle il montre la grande analogie du calcaire silicifié du Mont Bunza avec la CALCEDONITE de la Rhodésie, qui se présente sous le même aspect lithologique et avec les mêmes fossiles. Ce niveau de calcedonite n'appartient plus au Karroo qu'il recouvre en légère discordance, mais forme la base du SYSTEME DU KALAHARI.

Dans ces conditions, si l'assimilation proposée par M. Manfé est exacte, on aurait au Congo Belge, une limite supérieure à assigner au Karroo, limite qui serait, d'ailleurs, la même que celle indiquée en Afrique australe.

Ceci établi, nous allons résumer l'état actuel des connaissances acquises sur la stratigraphie du Karroo au Congo Belge.

a) dans la vallée du Kwango, à la limite de l'Angola portugais, il comprend une série, épaisse de plus de 600 m, formée presque entièrement de grès friables rouges ou blanchatres à stratification entrecroisée avec localement poudinque pisaire et psammite rouge;

b) La falaise de Kitari, dans la vallée de l'Inzia, à l'Est du Kwango, montre une série de grès comparable à la présédente. Cependant M. PASSAU y a découvert une intercalation argileuse de 2m de puissance renfermant des fossiles parmi lesquels:

Estheria.
Darwinula Globosa

indiquant l'age triasique ou rhétien de la formation.

Vers l'Est et vers le Nord, le niveau argileux se développe au détriment de la formation gréseuse inférieure. Dans la vallée de la Bushimaie, elle a 20 à 25 m de puissance; dans le bassin de la Lovoï, elle atteint 85m et les grés inférieurs n'ont plus que 15 à 20m de puissance.

Dans la vallée de la Lukuga, au voisinage du lac Tanganika, on trouve de haut en bas:

grès blanchatre et bigarré et grès rouge ou moins grossier	epaisseur au moins	50m.
schistes rouges et verts et quelques lits de calcaire noduleux et bancs de grès grossier	epaisseur environ	100m.
grès grossier feldspathique passant au poudinge pisane, schistes noirs, couches de houille	epaisseur environ	75m.
schiste noir avec bancs de psammite	epaisseur environ	50m.
conglomérat de base d'origine glaciarie	epaisseur extrement variable.	

La formation schisteuse a donc ici un développement plus grand encore; mais on voit à la base de la série s'intercaler entre le substratum ancien et le niveau schisteux avec lits calcaires, une formation nouvelle, gréseuse. schisteuse avec couches de charbon, fossiles végétaux parmi lesquels, on a

([10]) *Ann. Soc. Géol. de Belg. Public spéc. relat. congo.* année 1928-1929.

reconnu la présence de *Vertebraria.* Les assises supérieures sont parfois transgressives par rapport aux assises inférieures et les grès rouges viennent par endroits reposer directement sur le substratum cristallin.

Dans la région de la Luena (Lualaba) on exploite de la houille dans des conditions de gisement analogue.

Dans le Nord de la Colonie; la formation à houille n'a pas été signalée, mais la série schisteuse est bien caractérisée elle renferme des schistes bitumineux près de Stanleyville-Ponthierville ainsi que des intercalations calcaires.

C'est dans cette partie du bassin qu'elle a fourni la faune la plus typique comprenant notament:

Pelopleurus Maeseni	Leriche
Pholidophorus Corneti	Leriche
Lepidotus Congolensis	Hissakof
Colobodus sp.	
Esthériella lualabensis	Leriche
Estheria	
Darwinula Globosa	Duff
Metacypris Passaui	Leriche

Cette faune est d'age triasique supérieur ou jurassique inférieur; elle est plus récente que la flora à vertegraria qui caractérise la série à houille de la Lukuga.

Dans la région Nord du Congo à Buta et dans le Nord-Est à Irumu, le calcaire prend plus de développment encore.

En résumé, le systàme du Karroo comprend au Congo Belge un faciés entiérement gréseux dans le Sud-Sud-Ouest; vers le Nord-Nord-Est, la série supérieure est gréseuse, la série inférieure est essentiellement argileuse avec calcaire et grès.

Dans l'Est, une formation à couches de houille vient se placer en dessous de cet ensemble et constitue ainsi un étage inférieur du système.

On peut schématiser de la manière indiquée au croquis ci-dessous, la composition du Karroo au Congo Belge.

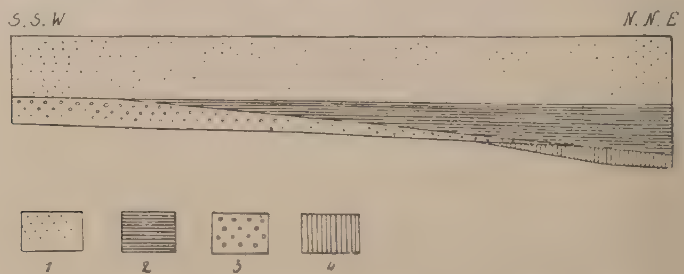

Schéma des facies du Karroo au Congo Belge

1. Grès supérieur;
2. Argilites, schistes rouges et bigarrés, schistes bimumineux, calcaires fossilifères
3. Grès inférieur;
4. Niveau à couches de houille.

Ce schéma met en évidence les variations de faciès; il permet, en tenant compte à la fois de la stratigraphie et des données paléontologiques, de distinguer dans le système du Karroo du Congo, trois étages:

1. ETAGE INFERIEUR ou de la LUKUGA à couches de charbon et à traces de GLOSSOPTERIS;

2. ETAGE MOYEN ou du LUALABA à faune rhétienne, dont le faciès varie du Sud-Sud-Ouest au Nord-Nord-Est.

3. ETAGE SUPERIEUR ou du SANKURU dont le faciès est essentiellement gréseux.

Je propose ainsi de subdiviser en trois étages l'ensemble des couches du Congo Belge que l'on peut rapporter au système du Karroo de l'Afrique australe.

III. RACCORD AVEC LES SUBDIVISIONS DU SYSTEME DU KARROO DE L'AFRIQUE AUSTRALE.

Ces faits étant établis, il y a lieu de rechercher a quelles divisions du Karroo de l'Afrique australe correspondent les trois étages définis ci-dessus.

On sait que le système du Karroo de la Colonie du Cap, là où il a sa composition type comprend de la base au sommet les quatre séries suivantes: ([11])

a) LA SERIE DE DWYKA est formée, à la base, de schistes, schistes argileux et quartzites avec restes indéterminables de plantes; au dessus vient la TILLITE DE DWYKA laquelle est recouverte à son tour par l'assise supérieure composée de schistes avec bandes de cherts et lits carbonatés. On y trouve des fossiles tels que *Mesosorus*, *Paléoniscus*, *Lépidodendron* etc. Dans le Sud-Ouest africain, il existe une faune marine dans cette formation.

b) LA SERIE D'ECCA est formée de schistes et de psammites avec grès et parfois des lentilles de calcaire; elle renferme une flore caractérisée par *Gangamopteris*, *Glossopteris*, *Phyllotheca*, *Schizoneura*, avec faune de poissons et de reptiles. Le faciès lithologique varie d'une province à l'autre. La série d'Ecca renferme du charbon principalement au Natal et au Transvaal dans sa pártie moyenne.

c) LA *SERIE* DE BEAUFORT est constituée dans sa partie inférieure par des grès alternant avec des schistes; il s'y trouve un peu de houille; la flore comprend des *Glossopteris*. La partie moyenne de la série comprend surtout des schistes et des grès avec concrétions calcaires fossilifères La partie supérieure est gréseuse avec zones schisteuses et un peu de calcaire;

([11]) Voir à ce sujet la publication récente de A. W. ROGERS, A. L. HALL, P. A. WAGNER et S. H. HAUGHTON: HANDBUCH DER REGIONALEN GEOLOGIE VII Bd. 7a. Abt. The Union of South Africa. Heidelberg 1929.

elle renferme des poissons, des sauriens et, comme végétaux, des *Glossopteris, Odontopteris* mêlés à des plantes appartenant déjà à la série supérieure, telles que *Thinnfeldia* et *Taeniopteris*.

d) La Serie de Stormberg comprend de bas en haut: Les Molteno Beds c'est-à-dire des grès, des schistes et un peu de calcaires avec localement des conglomérats et un peu de charbon exploitable localement. Les plantes des Molteno Beds sont: *Thinnfeldia, Taeniopteris;* on y trouve encore quelques *Glossopteris*.

Les Red Beds sont concordants sur les précédents mais ils peuvent s'avancer en transgression sur les couches de Beaufort; ce sont des schistes rouges avec grès rouges et grès jaunes feldpathiques; on y trouve des nodules calcaires passant à des lits de calcaire; cette assise renferme de nombreux restes de sauriens.

Le Cave Sandstone est représenté par des grès jaune-crême feldspathiques avec reptiles et astracodes.

Enfin, les Volcanic Beds couronnent la série.

Entre la région classique du Karroo et le Congo Belge on rencontre une série de bassins plus ou moins étendus occupés par le système du Karroo; leur étude permettra d'établir plus facilement le raccord entre les deux contrées.

Dans le bassin de Tete ([12]) (vallée du Zambèzè) le Karroo comprend:

a) Une Assise Inférieure composée principalement de schistes, avec couches de charbon; cette assise débute par un conglomérat de base. On y trouve *Glossopteris indica G. Browniana, Schizoneura Africana, Sphenopteris Lobifolia*.

b) Une Assise Moyenne, formée d'arkoses, grès, schistes, avec *Glossopteris*.

c) Une Assise Superieure ou dominent les grès fins et les psammites avec petites intercalations de schistes gris et violets. On y trouve d'importants épanchements volcaniques.

D'après les fossiles y rencontrés, on peut assimiler l'assise inférieure à la partie supérieure de la série d'Ecca; l'assise moyenne est alors l'équivalent de la série de Beaufort; l'assise supérieure représente la série de Stormberg, avec ses venues de laves au sommet.

Au Mont Waller, sur la rive occidentale du lac Myassa ([13]) on a distingué

([12]) Voir R. Anthoine et J. Dubois. Les grandes lignes de la géologie du bassin du Zambèze dans l'Est africain portugais. *Public. XIII sess. Congrès Géol. Intern.* Bruxelles 1922.
B. Karpoff. Sur les sédiments du Karroo en Afrique centrale et orientale. *Ann soc. Géol. de Belgique.* t. LII 1928-1929. *Bull.* p. 41.

([13]) B. Karpoff. Op. cit.

a) Une Serie Inferieure débutant par un conglomérat avec intercalations schisteuses et formée principalement de schiste, puis de schiste psammitique avec charbon sale;

b) Une Serie Moyenne dont les parties inférieures et supérieures sont grésseuses tandis que la partie moyenne renferme des couches de charbon et constitue la série productive du bassin;

c) Une Serie Superieure formée de grès argileux, de grès calcareux et de calcaires avec forte épaisseur de schiste d'intercalations calcaires à la base.

Au Nord-Ouest du lac Nyassa, se trouve le bassin de Kavolo, qui comprend: ([18])

a) Assise Inferieure formée de conglomérat grès grossier et calcaire rouge;

b) Assise Moyenne formée de grès, schistes avec charbon (série productive) et grès brun-jaune au sommet;

c) Assise Superieure grès rouges avec schistes à traces de charbon à la base.

La succession est comparable à celle du Mont Waller; toutefois le charbon est seulement dans l'assise moyenne et, d'autre part, l'assise supérieure est formée principalment de grès à la base.

On voit ici nettement la parenté avec la formation du Karroo telle qu'elle a été décrite dans la région voisine du lac Tanganika (vallée de la Lukuga). L'assise inférieure du bassin du Kavolo correspond aux conglomérats et schistes inférieurs à la formation à charbon de la Lukuga; quant à l'assise supérieure, elle correspond à l'assise schisteuse et aux grès rouges qui, à la Lukuga, surmontent la série à charbon.

La comparaison de ces diverses coupes montre que du Sud vers le Nord, la série à charbon occupe une position stratigraphique de plus en plus élevée dans le système du Karroo.

Nous arrivons ainsi à figurer comme suit le raccord entre le formation du karroo au Congo Belge et la succession type de l'Afrique australe.

	Afrique Australe.	Congo Belge.
Stormberg.	Cave Sandstone .... Lava Beds	étage du Sankuru
	Red Beds .... Molteno Beds	étage du Lualaba
Beaufort.	supérieur .... moyen .... inférieur	étage de la Lukuga
Ecca		
Dwyka.		

Il n'est pas possible de préciser actuellement si l'étage du Lualaba correspond aux Red Beds ou bien à l'ensemble des Red Beds et des Molteno Beds; l'autre part, l'étage de la Lukuga, renfermant des restes de glossopteris, peut être rapporté à la série de Beaufort, ou à une partie de celle-ci, mais comme on trouve encore ce fossile dans les Molteno Beds, on peut se demander si l'étage de la Lukuga n'empiète pas aussi sur les Molteno Beds ou ne représente pas simplement ces derniers.

Il reste ainsi quelques incertitudes que seule pourra faire disparaitre la découverte de fossiles.

21. CONTRIBUZIONE ALLA PALEOXILOLOGIA DELL'AFRICA

PER

PROF. DR. ALBERTO CHIARUGI,
(Dall'Istituto Botanico della R. Università di Firenze, Italia).

Lo studio di campioni provenienti dalle foreste pietrificate dei dintorni di Giarubùb (Cirenaica) (1) e di varie località della Sirtica (2) ha dimontrato che la Libia rientra in pieno nell'ambito di quella "flora fossile sahariana" di tipo tropicale, che costituisce le famose "foreste pietrificate del Cairo" (14, 11, 12, 9), segnalate nella bassa Valle del Nilo fino dagli scienziati della spedizione francese in Egitto del 1799, e che poi vennero da successive spedizioni riconosciute estese anche nell'interno dei deserti che circondano quel paese.

Lo studio dei campioni libici ha dimonstrato che alcune specie, finora conosciute soltanto dell'Egitto (*Palmoxylon libycum* (STENZEL) KRÄUSEL, *Palmoxylon Aschersoni* SCHENK) si estendono molto più ad occidente sul margine settentrionale del Grande Erg Libico. Per altre specie, la cui esistenza era già stata segnalata in Tunisia (8) o anche più ad occidente (13) (*Nicolia aegyptiaca* UNGER, *Ficoxylon cretaceum* SCHENK), viene stabilita una nuova stazione intermedia assai utile per precisare l'area geografica della specie. Vengono infine descritte tre specie nuove: una monocotiledone, *Palmoxylon giarabubense;* e due dicotiledoni, *Nicolia giarabubense, Laurinoxylon Desioi;* la prima assai affine alla *N. aegyptiaca,* la seconda forse affine al *L. primigenium* SCHENK.

La florula di Giarabùb (1,5), raccolta dal DR. A. DESIO durante la Spedizione della Reale Società Geografica Italiana nel 1926, risulta di sei specie: *Palmoxylon Aschersoni* SCHENK, *P. libycum* (STENZEL) KRÄUSEL, *Palmoxylon giarabubensis* CHIARUGI, *Nicolia aegyptiaca* UNGER, *Nicolia giarabubensis* CHIARUGI, *Laurinoxylon Desioi* CHIARUGI.

La florula della Sirtica (2), raccolta nel 1927 dal Maggiore I. GEROLA, a Maatem Risàm e alcune altre località prossime, risulta di tre specie: *Palmoxylon cretaceum* (STENZEL) KRÄUSEL, *Laurinoxylon Desioi* CHIARUGI, *Ficoxylon cretaceum* SCHENK, alle quali va aggiunto il *Palmoxylon Aschersoni* SCHENK, raccolto dal signor U. CONTE nel 1928 a Gialo.

Un esemplare di *Dadoxylon aegyptiacum* UNGER fu portato dal Fezzan (Libia) dalle foreste pietrificate di Secba dal Tenente G. RELLINI durante la Spedizione Miani nel 1914 (3, 4).

La flora fossila sahariana non si estende però soltanto lungo il margine settentrionale del Sahara, ma si estende anche a regioni meno strettamente in rapporto col Grande Deserto Africano. Questo risulta già dal fatto che la *Nicolia aegyptiaca*, elemento caratteristico di questa flora e la cui area di distribuzione è la più vasta conosciuta, si estende non solo dalla costa atlantica del Sahara (12) alle valle del Nilo, ma si inoltra fin sugli altipiani dell'Etiopia (15) e nella Somalia Britannica (7).

Lo studio della flora fossile dalla Somalia Italiana rende questo fatto ancor più evidente, perchè la *Nicolia aegyptiaca* si estende fin sulle rive dell'Oceano Indiano (1) sui terreni terziari della Migiurtina (bacino del Darror), ove trovasi non più isolata, come in Etiopia e nella Somalia Britannica, ma accompagnata da un'altra specie fossile finora conosciuta esclusivamente delle foreste pietrificate del Cairo, il *Dombeyoxylon aegyptiacum* SCHENK.

Ma non soltanto l'Africa Orientale viene sfiorata dall' àrea di specie fossili sahariane, bensì anche l'Isola di Sardegna. Difatti nel giacimento miocenico di Zuri, nel bacino del Tirso, risulta presente tanto il *Dombeyoxylon aegyptiacum* SCNENK, quanto il *Laurinoxylon Desioi* CHIARUGI (6).

In tal modo la Sardegna viene a possedere, a lato di altre specie, due elementi caratteristici delle foreste pietrificate sahariane: uno che attraverso l'Egitto arriva fino all'Oceano Indiano, e un altro che per ora in Africa si trova solo in Libia, dove però è accompagnato da specie (*Nicolia aegyptiaca*, *Ficoxylon cretaceum*, *Palmoxylon libycum*, *Palmoxylon Aschersoni*) che alla lor volta sono associate alla prima nei giacimenti egiziani, ed una delle quali (*Nicolia aegyptiaca*) lo è anche in quelli somali.

La flora fossile di Somalia, raccolta dal Prof. G. STEFANINI, e la cui illustrazione comparirà tra breve, si suddivide in due giacimenti ben distinti: uno in Migiurtinia nel bacino del Darror, su terreni eocenici, con legni silicizzati di specie a tipo tropicale, fra le quali compaiono le due specie sahariane surricordate; l'altro nel Benadir a Scec Gure su terreno cretaceo con legni silicizzati di specie tipo equatoriale; esso non presenta nessun elemento sahariano, ma invece una diecina di specie appartenenti a *Palmoxylon* (*P. somalense*, *P. benadirense*, *P. scebelianum*), a *Dipterocarpoxylon* (*D. somalense*, *D. giubense*, *D. scebelianum*), a *Sapindoxylon* (*S. benadirense*) ecc. La presenza di numerosi *Dipterocarpoxylon* permette di rilevare qualche affinità coi giacimenti indiani e malesi, e in particolare con quelli illustrati dal KRÄUSEL (10) nel terziario di Sumatra.

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ABSTRACT.

CONTRIBUTION TO PALEOXILOLOGY OF AFRICA.

The study of silicified woods from Cirenaica and Sirtica revealed, also in Libia, the presence of certain specimens already known in classic deposits of Egypt (*Nicolia aegyptiaca* UNGER, *Ficoxylon cretaceum* SCHENK, *Palmoxylon libycum* KRÄUSEL, *P. Aschersoni* SCHENK, besides other specimens described as new ones (*Laurinoxylon Desioi, Nicolia giarabubensis, Palmoxylon giarabubense*).

The aegyptian fossil flora, with tropical character, extends not only in the Saharian Region, but till Migiurtinia (Italian Somaliland): in Darror deposits, on eocenic soil, are present *Nicolia aegyptiaca* and *Dombeyoxylon aegyptiacum* SCHENK.

The area occupied by *Dombeyoxylon aegyptiacum* is much more wide than the area till now known (Egypt), for I have recognized it not only in silicified woods from Somaliland, but also in some ones from Sardinia (Italy), coming from the basin of Tirso. The aegyptian fossil flora extends so also out of Africa in the territory of the *Tyrrhenis*.

In Benadir (Italian Somaliland) any representative of aegyptian flora has not been found. The flora of Scec Gure deposits, on cretaceous soil, has equatorial character and shows some affinity with Sumatra (Malesia) fossil flora. This flora is represented by a ten specimens of *Palmoxylon, Dipterocarpoxylon, Sapindoxylon,* etc.

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● ——— Stazioni ed area del Dombeyoxylon aegyptiacum Sckenk
○ ······ » » » » Laurinoxylon Desioi Chrg.
+ – – – » » » della Nicolia aegyptiaca Unger
× —··—··— Stazioni ed area del Ficoxylon cretaceum Sckenk
□ —·—·—·— » » » » Palmoxylon libycum Kräusel
⌒ » Aschersoni Sckenk

22. SUR UNE TRANSFORMATION METASOMATIQUE PARTICULIERE DES GRES SUPERIEURS DU BASSIN DU CONGO
(Formations Synchroniques du Karroo)

PAR

J. LOMBARD.

Parlant des grès supérieurs du bassin Congolais, A. L. DU TOIT écrit (1): "This formation........is composed of horizontal friable white, yellowish, or "reddish sandstones, often displaying curious surface silicification."

C'est, à mon avis, BALL et SHALER (2), qui ont le mieux résumé les transformations que subissent ces grès sous l'action combinée de l'eau et des facteurs climatériques. Ces transformations aboutissent aux variétés de structure des "grès polymorphes" de J. CORNET, (3) c'est à dire à des aspects de grès quartziteux, opaloïde ou meuliérisé.

On trouve, dans les alluvions les plus anciennes du Congo, dans les environs de Brazzaville, de nombreux galets provenant de la destruction de bancs ou blocs de ces roches très dures. Un certain nombre de ces galets sont enduits superficiellement d'une couche peu résistante qui, sous le seul effet de l'ongle, se résout en une poussière impalpable dont le toucher est absolument kaolineux. La matière est blanche, jaunâtre ou grisâtre suivant les impuretés qu'elle contient—toujours en faible quantité.

L'analyse chimique (4) révèle, en effet, qu'on est en présence d'une silice très pure: la perte à la calcination, sur la matière desséchée à l'étuve à 100 C, s'exprime par 0,41%. L'attaque à l'acide fluorhydrique laisse un résidu d'oxydes métalliques qui représente 0,72%.

(1) ALEX L. DU TOIT.—A geological comparison of South America with South Africa Washington, 1927.

(2) S. H. BALL et M. K. SHALER.—Contribution à l'étude géologique de la partie centrale du Congo Belge, y compris la région du Kasaï (Annales de la Société Géologique de Belgique; Publications relatives au Congo belge et aux régions voisines tome XXXIX, Liége, 1913).

(3) J. CORNET—Les formations post primaires du bassin du Congo (Annales de la Société Géologique de Belgique, tome XéI, Mémoires, Liége 1894).

(4) Analyses dues à M. R. COULON, Chef du Laboratoiré du Service des Mines de l'Afrique Equatoriale Française, à Brazzaville

Je puis donc désigner le minéral ainsi analysé, qui contient 98,87% de silice par le nom de silice alphitique ([5]).

J'ai trouvé, dans le cailloutis de la Briqueterie, à Brazzaville ([6]), un galet constitué entièrement par le minéral ainsi défini. Il est évident que s'il avait eu originellement cette constitution, ce galet n'aurait pas résisté aux conditions torrentielles qu'il a subies lors de son dépôt; il aurait été entièrement désagrégé. On est donc conduit à admettre que la silice alphitique résulte d'une transformation sur place de la masse primitivement dure et compacte, opaloïde. D'autres éléments fréquents dans les cailloutis confirment cette hypothèse. En effet, on trouve des galets constitués par des lits alternés d'opale ([7]) et de silice alphitique. On y observe, dans un même lit, des passages latéraux de l'une de ces formes de silice à l'autre.

Ce phénomène constitue, sans nul doute une réapparition de la stratification originelle au sein d'une masse apparemment parfaitement homogène (l'opale provient, je le rappelle, d'une première transformation des grès friables; figure 1.)

Ce n'est pas le moindre intérêt de ces observations que de mettre ainsi en évidence un caractère physique pour lequel les opales en question ne sont qu'apparemment isotropes.

Il arrive même que des galets sont coupés en plusieurs morceaux solides limités par des faces rigoureusement planes enduites d'une mince couche de silice alphitique (figure 2).

Dans certains cas encore, a eu lieu un remaniement de la silice qui aboutit à des concrétions pisolitiques, dont les couches concentriques offrent également des alternatives de matière solide et d'enduits alphitiques (figures 3 et 4.)

Enfin, on trouve des morceaux roulés d'opale présentant à la fois des géodes tapissés de beaux cristaux de quartz et des enduits alphitiques.

Cet ensemble d'observations me semble bien prouver le *caractère métasomatique* de la transformation.

Si la différence d'aspect physique s'accompagne d'une variation dans la composition chimique, celle-ci doit être mise en évidence par l'analyse.

La méthode définie plus haut donne:

	Opale	Silice alphitique
perte à la calcination	0,71	0,41
oxydes métalliques	3,15	0,72

([5]) du grec "ἄλφιτον" farine. J'adopte cette épithète pour rester en harmonie avec la dénomination *d'alphitites* donnée par certains auteurs (Salomon) à des formations argiloïdes non constitués par des silicates d'alumine.

([6]) Cf. J. Lombard.—Sur l'origine fluviatile des sables de Brazzaville (C.R.S. Sté Géologique de France, Décembre 1928).

([7]) Je qualifie *d'opale* la matière des galets en raison de son aspect extérieur parfaitement amorphe et coloré dans les tons gris et bleu gris, et de son isotropie optique. J'aurais adopté le mot "silex" s'il était mieux défini.

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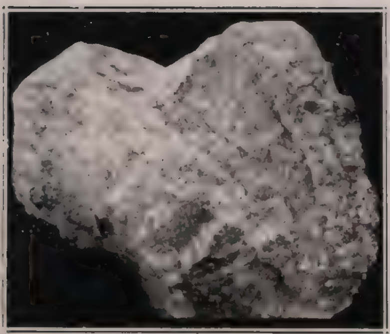

Fig. 1. (réduction an ¼)

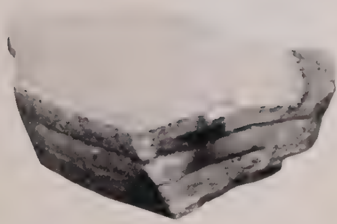

Fig. 2. (grandeur naturelle).

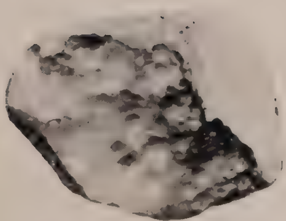

Fig. 3. (grandeur naturelle).

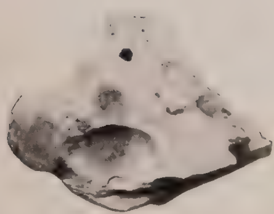

Fig. 4. (grandeur naturelle).

Transformation metasomtaique des grès supérieurs, Bassin du Congo.

Communication No. 22

Un échantillon de quartz bien cristallisé et de même provenance a donné:

perte à la calcination 0,49

Le seul facteur qui pourrait être pris en considération pour expliquer la transformation de la matière serait l'hydratation.

Or sa constance est très remarquable. Le même problème se pose donc ici pour la transformation du quartz en opale et de l'opale en quartz, que pour la désagrégation en silice alphitique.

J'ai recueilli, en divers endroits, des grès friables bien en place, particulièrement aux fameux "Dovers Cliffs" où la formation gréseuse tombe à pic dans le Stanley Pool. Indépendamment des grains de quartz fins mais bien formés qui constituent ce grès très friable on y trouve en petite quantité une poudre siliceuse impalpable, blanche, que j'identifie avec une quasi certitude à la silice alphitique ci-dessus décrite. Cette observation généralise dans la région la présence de cette nouvelle forme de la silice et exclut, pour sa formation, l'intervention nécessaire d'une transformation préalable en opale ou en silice compacte.

Une application pratique de ces observations réside dans l'explication de l'aspect argiloïde de certaines formations fréquentes dans les alluvions modernes du Congo.

L'analyse chimique ([8]) leur assigne la composition suivante:

Perte à la calcination	5,14
Silice libre	72,60
Silice combinée	9,32
Al^2O^3	9,93
Fe^2O^3	1,25
CaO	0,24
MgO	0,97
Alcalis et éléments non dosés	1,95

Les briques que l'on a tenté de fabriquer avec cette matière sont complètement dénuées de consistance. En fait, la quantité de silicate d'alumine possible d'après les résultats de l'analyse, est insuffisante pour assurer la cohésion après cuisson. Elle ne peut pas davantage expliquer l'aspect argileux de la masse.

Par contre la présence de silice alphitique dans les 64% de silice libre (sable) qui passent au tamis N° 120 me parait fournier une explication suffisante de ce caractère physique anormal.

Je rappelle que des propriétés analogues ont déja été signalées pour la dolomie.

([8]) Due à M. R. Coulon.

23. SUR L'EXISTENCE ET DISTRIBUTION DU KARROO DANS L'ANGOLA

PAR

A. Borges et F. Mouta,
Ing. *I.S.T.*

Sommaire.

Notice Explicative.

Pour ne pas encombrer davantage la nomenclature géologique, déjà si riche, on a cherché tant qu'il nous a été possible, à éviter de nouvelles désignations.

Ainsi, dans la plupart, nous avons adopté celles déjà connues dans l'apercu de la géologie générale de l'Angola, publié par M. Bebiano ([22]) mais il nous semble préférable d'écarter les nombreuses désignations locales de cet auteur.

Le tableau I résume ces modifications:

Système du Bembe.—

On a retiré de ce système les couches de Damba et Maquela, puisqu'elles appartiennent incontestablement au système supérieur du Kundelungu.

Système de Malange (Kundelungu.)

Nous avons remplacé la désignation de S. de Lui par celle de Malange par différentes raisons:

a) les couches de la vallée du Lui ne répresentent que la partie inférieure de notre Kundelungu (horizon IV ou couches de Mpioka); poùr celles-ci nous conservons la désignation de couches du Lui.

b) la partie supérieure (horizon V ou couches de l'Inkissi) se trouve dans le plateau de Malange, bien représentée dans la vallée du Lombe. Le nom de Malange est bien connu et à ce district appartient le bassin du Lui. Les couches de Malange, du S. du Lubilache de M. Bebiano, rentrent dans cet horizon.

Dans les couches de Pungo Adongo, le même auteur distingue des grès ferrugineux, presque horizontaux, et le conglomérat. Nous verrons plus lon que les couches inférieures appartiennent au Kundelungu et que le conglomérat sous-jacent pourrait, par sa position, être assimilé à la base du Lubilache.

Système du Dondo.—

Le conglomérat du Dondo étant déjà bien connu et admettant qu'il doit constituer la base de nos grès rouges sublitoraux de la même région, nous avons gardé cette nomenclature, séparant les couches gréseuses, couches de Quilungo, et le conglomérat, couches du Dondo.

Les grès de Dombe Grande, qui ont été mis en parallèle avec les couches de Quilungo, appartiennent au crétacé, comme nous l'avons montré dans un travail prédédant ([1]).

Système du Haut Zambèze.—

Un faciès différent du Lubilache nous a fait séparer les formations du Haut Zambèze. Pour le moment, nous n'y considérons que une série sédimentaire et une série volcanique.

Système Gréseux.—

Comme nous verrons dans la suite, dans ce système sont compris les grès qui, au Nord, se rattachent à ceux du Bassin du Congo (S. du Lubilache) et qui vers le Sud semblent passer à ceux de la cuvette du Kalahari.

Les "Bié sandstones" de GREGORY (2), représentant le Lubilache dans cette région, et qu'il croit comme l'origine des sables de Bulu-Vulo, sans cependant mentionner leurs affleurements, n'ont pas été aussi trouvés par nous.

D'après la connaissance que nous possédons de la région, nous sommes d'avis que tous ces sables proviennent des quartzites très anciens qui abondament traversent la région et qu'on voit même au sommet de la ville du Bié; ces roches, altérées, se présentent comme de veritables grès.

Le tableau II donne la corrélation de notre échèlle avec les systèmes de l'Afrique Centrale et du Sud. Cette assimilation, on le sait très bien, est toujours douteuse par l'absence de fossiles.

TABLEAU I.

CORRÉSPONDENCE DES ÉCHÈLLES STATIGRAFIQUES.

	M. BACELAR DEBIANO.
SYSTÈME DU BEMBE: (Schisto-calcaire.)	SYSTÈME DU BEMBE: Couches du Bembe. Couches de Zanga et Cacolo.
SYSTÈME DE MALANGE: (Kundelungu.) Couches de Lui.	SYSTÈME DU BEMBE: Couches de Damba et Maquela. SYSTÈME DE LUI: Couches de Bungo, Della et Cuillo. Couches de Lui.
Couches de Lombe. Couches de Lui.	SYSTÈME DU LUBILACHE: Couches de Malange. Couches de Pungo Adongo (inf.)
SYSTÈME DU DONDO: (Grès sub-litoraux.) Couches du Quilungo. Couches du Dondo.	Couches de Libongo et Musserra. Couches de Quilungo et Caxibo.
SYSTÈME DU HAUT ZAMBÈZE: Série Sédimentaire. Série volcanique.	
SYSTÈME GRÈSEUX: Grès polymorphes. Grès tendres. Conglomérats assimilés.	SYSTÈME DU LUBILACHE: Couches de la Lunda. Couches du Lucória. Couches du Pungo Adongo (Conglomérat.)

TABLEAU II.

ANGOLA.	CONGO OCCIDENTAL.	KATANGA.	RHODÉSIE DU SUD.	AFRIQUE DU SUD.	EUROPE.
Système du Bembe.	S. Schisto Calcaire	S. de Lubudi.	S. de Lomagundi?	Transvaal System?	—
S. de Malange:					
Couches de Lui.	C. Mpioka.	Horiz. IV. (S. Kundelungu)		Ecca et Beaufort. (S. Karroo.)	Permien.
Couches de Lombe.	C. de l'Inkissi.	Horiz. V. (S. Kundelungu)			
S. du Dondo:					
Couches de Quilungo.	Grès sub litoraux.	•			Triasique Sup.?
S. du Haut Zambèze:					
S. Sedimentaire	—	—	Escarpment grits, forest sandstones.	Stormberg. (S. Karroo.)	Rhétien.
S. Volcanique.	—	—	Batoka basalts.		
S. Gréseux:					
Conglomerats de Pungo Andongo et Bié.	S. Lubilache.	S. Lubilache.	—	Stormberg?	Rhétien.
Grès tendres.					
Grès polymorphes fossilifères.	Couches du Mt. Bunza.	—	Kalahari Chalcedony?	Kalahari?	Crétacé ou Eocène?
Dolérites intrusives	—	—	—	Intrusions post Karroo.	—

Géographie Physique.

Au point de vue orographique, nous pouvons distinguer, d'après l'éxamen de l'esquisse hypsomètrique, où sont localisées nos coupes, les zones suivantes:

I.—Zone litorale (o à 400 m.)
II.— " subplanaltique (400 à 1,000 m.)
III.—Le premier grand plateau (1,000 à 1,500 m.)
IV.—Le deuxième grand plateau (au dessus de 1,500 m.)

I.—*Zone litorale* (o *à* 400 *m.*)

La zone litorale est limitée à l'Èst par le grand degré du plateau au dessus de 1,000 mètres, entre les parallèles -o° et 13°, au en être séparée par une bande subplanaltique, au Nord et au Sud de ces limites.

Sa largeur est variable, dès un maximum de 200 kilomètres au Cuanza, se réduisant rapidement jusqu'à disparaître au Sud de Benguella, là où les formations cristallines viennent à la côte, pour s'élargir après, vers Mossamedes et la vallée du Cunène.

Les formations marines, crétacées et tertiaires, y reposent sur les roches cristallines (gneiss), les premières, surtout au District de Benguella, se présentant en gradins succéssifs, jusqu'au nombre de quatre, et atteignant l'altitude de 400 mètres exceptionnelement.

II.—*Zone subplanaltique* (400 *à* 1,000 *mètres.*)

Cette zone se distribue irrégulièrement du Nord au Sud de la Colonie.

Au Nord du Cuanza, elle se maintient entre 400 et 600 mètres et de ce niveau passe brusquement au Plateau de 1,000 mètres; vers le Sud, elle se réduit à l'étroite bande qui, dans les régions de Amboim Selles et Lengue, constitue le vrai degré du premier grand plateau.

Plus au Sud, la zone subplanaltique s'élargit de nouveau, avec un maximum de 200 kilomètres sur le parallèle 14°, mais au contraire de ce qu'on a vu au Nord, elle y monte lentement pour venir buter contre le grand escarpement de la Chela.

La région subplanaltique est très montagneuse, sauf au Congo, bien qu'elle y soit accidentée.

Dans cette zone on trouve, outre les roches cristallines, les roches métamorphiques, et une partie du système schisto-calcaire dans le Nord.

Des altitudes inférieures à 1,000 mètres se trouvent encore soit au Nord de la Colonie (Congo et Lunda, dans les bassins du Cuango et Cassai) soit dans le Sud, au Cunène, en aval des chûtes de Ruacaná.

III.—*Le premier grand plateau* (1,000 *à* 1,500 *m.*)

Au Sud du Cuanza, il est très montagneux, d'où émergent les plus hauts massifs de l'Angola (2,600 mètres) entre les parallèles 12° et 13°.

Le paysage est caractérisé par la présence de gigantesques monolithes (inselnbergen) et amas granitiques; au Nord, les roches cristallines et métamorphiques sont superposées par les formations du Karroo.

En dehors de cette zone, la plus grande partie de la Colonie, à l'Èst et au Sud, est comprise dans des altitudes moyennes, dépassant très rarement, à Munhango (1,530 mètres), et de l'autre côte du Zambeze, à Calunda (1,650 mètres.)

C'est la région de relief le plus faible, essentiellement sableuse, soit formant de vastes plaines, herbeuses (xanas), soit creusée par de profondes vallées.

IV.—*Le deuxième grand plateau* (*au dessus de* 1,500 *mètres.*)

Il n'existe pas au Nord du Cuanza et, au Sud, il constitue le Plateau de Benguella qui se prolonge par une étroite bande dans le Plateau de Mossamedes. Sa direction générale est NE-SO.

Ce plateau est limité le plus souvent, à l'Ouest, par une descente abrupte, et vers l'Èst descend graduellement aux niveaux inférieurs; près de sa bordure occidentale se lèvent encore de grands massifs qui dépassent les 2,000 mètres, et disparaîssent complètement à l'Èst du méridien 16°-30'.

Les altitudes au dessus de 1,800 mètres se trouvent dans le petit Plateau de Humpata (District de Huila) isolé complètement par de falaises; à l'Ouest il tombe verticalement sur la zone des 1,000 m. constituant le très connu escarpement de la Chelle.

Des formations sédimentaires anciennes, encore non corrélationnées, prennent dans cette région élevée un grand devellopement (Oendolongo, Lépi, Calenga, Bailundo, Huambo, etc.), aussi bien que les granites intrusifs.

Le Plateau de Humpata est couronné par un système sédimentaires, le Système de la Chella à rapporter au Système de Nama, du Sud-Ouest Africain.

I. Systèmes Gréseux.

1) *Grès Polymorpkes.*

Stratigraphie.—

Sous cette désignation nous considérons le type de roches qui ont été si bien décriptes par M. Cornet: des roches siliceuses, dures, se présentant comme un grès aglutiné par de la silice de seconde formation et montrant, quelquefois sur le même bloc, des très variées ([8]).

On les trouve en Angola un peu partout, soit dans les alluvions fluviales, soit "in situ" en couches se divisant en blocs, quelquefois très volumineux, et qui reposent sur les grès friables (dans le Luêna et dans le M'Simoje à Moxico.)

Les grès polymorphes sont aussi mélangés à une roche fossilifère que M. de Rauw vient de signaler, au Mont Bunza, quelques kilomètres au Nord de la frontière de la Lunda, constituant un dépôt local, isolé au sommet des grès friables ([4].)

Nous avons eu la bonne fortune de, plus récemment, avoir trouvé bien plus au Sud, dans le District de Malange (plaine de Cassange), un autre gisement, dans des conditions analogues, mais reposant sur les schistes gréseux du Kundelungu.

Ce dépôt couvre quelques kilomètres carrés de surface et est limité au Nord par une falaise, orientée N-45°-W, de 50 mètres de hauteur, se réduisant vers le Sud jusqu'à disparaître. Cette falaise est sans doute, due à des couches sur place comme au Mont Bunza.

La roche fossilifère de Cassange est aussi identique et, outre des espèces dejà décriptes, elle contient de formes nouvelles, que M. Leriche a bien voulu se charger de determiner.

Malgré l'impossibilité, sur le gisement même, d'une séparation nette des couches fossilifères et stériles, cette séparation doit exister, puisque dans tous les autres affleurements de grès polymorphes, on n'a rien vu. La roche elle même, diffère par son caractère plus uniforme, se présentant toujours plus silicifiée, bien qu'au microscope on voit encore quelques grains de quartz primitifs, ce que prouve, comme a très bien remarqué M. de Rauw "que le calcaire était de nature plus ou moins sableuse, et c'est par conséquence déposé au voisinage d'un rivage."

Les grès polymorphes non fossilifères se rencontrent à des différents niveaux de la série du Lubilache, soit sur les grès friables supérieurs, soit sur la partie plus argileuse de la base, devant être formés sous des conditions spéciales de climat.

La coupe relevée dans la falaise du Cuando, près de sa source au parallèle 13-30° de latitude Sud, montrent la marche du phénomène.

Age des grès polymorphes fossilifères.

Malheureusement, nous n'avons pas encore reçu le résultat de la détermination des espèces de Cassange, mais cependant il nous semble possible de donner déjà quelques suggestions.

Rappelons que en Rhodésie du Sud, dans la limite orientale des formations du Kalahari, dans la couche irrégulière de "chalcedonic quartzite" sous les sables rouges, M. Maufe refère l'existence de coquilles d'eau douce, rapportées au genres *Viviparus*, *Paludestrina*, *Limnea*, *Isidora*, *Melania*, et deux ou trois espèces de *Chara*. Newton, qui les a classifiées émèt l'opinion que ces fossiles peuvent indiquer l'âge Crétacé Supérieur ([5]).

Dans le Nord du Kalahari, dans une variété de calcaire de surface (Pfannenkalktuff de Passarge), M. Du Toit mentionne aussi les genres *Succinea, Planorbis, Physa, Viviparus, Melania,* et des *Diatomées.* ([6]).

L'éminent géologue, si bien au courrant de la géologie africaine, suppose pour ces formations du Kalahari, une même époque probable de déposition, Éocène ou encore plus ancien, que les formations du Sud du Cap, ce que lui est admissible par la présence dans les roches siliceuses de ces deux régions, des genres *Chara* et *Limnea.*

Avant de avoir eu connaissance des gisements de Cassange et du Mont Bunza et aussi des travaux de M.M. de Rauw et Leriche, nous avons été frappés par la continuité de faciès des grès polymorphes, du Nord au Sud de la Colonie, jusqu'aux affleurements de roches siliceuses qu'on trouve dans les dépoôts fluvials de la vallée du Cubango (Okavango) et d'autres tributaires du Kalahari.

Dans les gisements de l'Angola et du Congo, une association analogue de genres se trouve: *Physa* (deux espèces), *Planorbis, Chara,* et seulement le genre *Cypris* (le plus abondant mais non caractéristique) n'a été signalé dans l'Afrique du Sud.

Ces analogies lithologiques et paléontologiques ne sont elles pas de nature à admettre que les mêmes conditions de vie et de climat du Sud se sont étendues jusqu'au Congo?

Dans les formes décriptes par M. Leriche ([7]), celles "qui ont pu être caractérisées sont toutes nouvelles, de sorte que elles ne peuvent servir à determiner d'une manière précise l'âge du dépôt." C'est seulement par l'approximation de son espèce de *Physa à Physa Wealdiana,* du Puberckien du Jura, que M. Leriche suppose que les couches du Lubilache, dont il fait dépendre les roches fossilifères, "renferment peut-être, en plus du Trias Supérieur et du Rhétien, une partie du Jurassique," et pour cela il fait remonter l'apparition du genre *Physa,* à une époque probablement plus reculée que le Puberckien d'où proviennent les plus anciennes *Physa* connues jusqu'ici.

Il est aussi intéressant d'ajouter l'opinion déjà émise par M.M. Dolfus et Rupert Jones sur lâge, Tertiarire ou Mesozoique, d'une roche appartenant sans aucune doute au gisement de Cassange et contenant des coquilles de *Cythere* et de *Cytheridea.*

L'échantillon examiné était un cailloux dont la description et localisation donnée par Choffat ([8]), "un cailloux de pierre meulière, probablement d'origine limnique," nous a permis sans hesitation de la rapporter à notre gisement.

En conclusion, nous cryons que les couches fossilifères du Congo et de l'Angola peuvent être regardées comme plus récentes que les suppose M. Leriche, ces dépôts représentant les derniers stages d'exondation du grand lac lubilachéen ([4]).

2. Série des Grès Tendres.

Stratigraphie.—

La série comprend des grès tendres, friables, blancs, jaunâtres ou rouges, ayant quelquefois à la base un conglomérat, mais plus généralement une couche de grès plus argileux et toujours rouge.

La roche est constituée par des grains de quartz, roulés et fins, souvent envellopés par une mince pellicule argilleuse ou siliceuse, et pouvant contenir des petits cailloux disséminés.

Les grès affleurent très rarement, puisqu'ils sont toujours recouverts par des sables blancs et rouges, atteignant ce dépôt sperficiel plus de 200 mètres d'épaisseur.

La partie inférieure de la série est constituée, comme nous l'avons dit plus haut, par une couche de grès argilleux, rougeâtre, micacé et ayant parfois intercalés des lits minces de argillite rouge vif et des cailloux, la roche devenant un peu plus grossière. C'est ce qu'on a vu à Lunda, sur le conglomérat de base au Camissombo, sur les gneiss à Luaco, et dans le Sud, à Cangamba sans y voir le substractum.

Au Sud du parallèle 9°-30 , à peu grès, la série n'est représentée que par la couche de grès rouge, argilleux, affleurant dans les vallées de quelques rivières, sous la forme de petites falaises sans continuité; la puissance maximum est de 10 mètres, mais la moyenne ne depásse pas 3 mètres.

Cette couche, qui semble être toujours la même, par sa position dans les différentes coupes et uniformité lithologique, présente une stratification entrecroisée, irrégulière, indiquant un faciès peu profond.

Le fait que cette couche est tojours recouverte par les sables superfiels, et exceptionnellement par les dolérites, et l'identité à celle qui au Nord repose sur le conglomérat, nous fait admettre qu'elle représente le système vers le Sud.

Le conglomérat de base est formé d'un cimet gréseux, unissant des cailloux roulés, ou même anguleux, de dimensions variables atteignant jusqu'à 15 cm., et constitués par des roches siliceuses. A Luaco, il est diamantifère et a été traité en donnant 0,1 carat par mètre cube.

La série plus complète a été observée à Camissombo:

Sables rouges	95	mètres.
Grès friables	60	,,
Grés argilleux	2	,,
Conglomérat	4	,,
Kundelungu		

Une silicification sécondaire peût se rencontrer à tous les niveaux, comme nous avons parlé à propos des grès polymorphes, mais quelquefois le phénomène a produit seulement un endurcissement de la roche, qui devient un quartzite, d'aspect vitreux, où on voit encore la stratification primitive.

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Fig. 1.

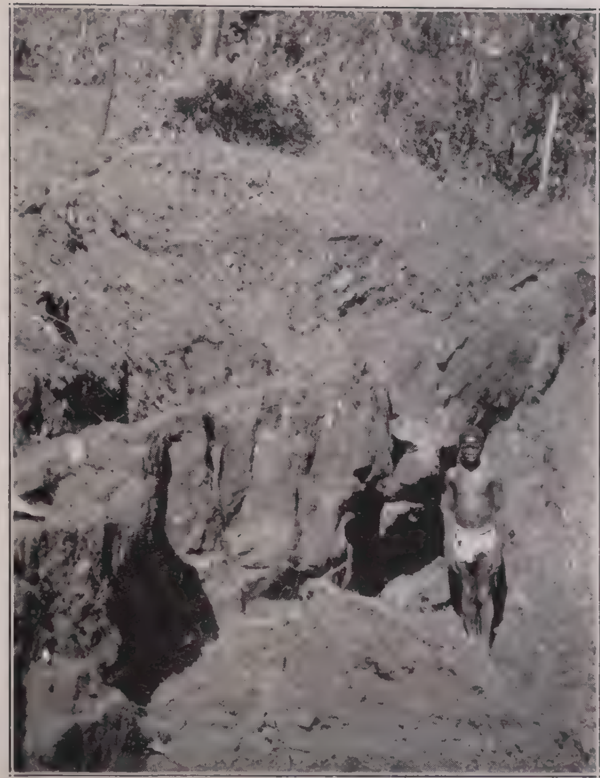

Fig. 2.

Fig. 1. Dolerite intrusive dans les grès tendres—Cuemba.
Fig. 2. Contact des dolerites avec les grès tendres—Cuemba.

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Les couches de cette série plongent dans l'ensemble très faiblement vers l'Ést; exceptionnellement au Nord, à Cacólo, elles plongent vers l'Ouest de 30° à 40°.

La présence des dolérites peût modifier la regularité des couches, immédiatement inférieures, et on mesure des valeurs entre 15° et 25°.

Dolérites intrusives.

Deux grandes intrusions de ces roches traversent la région à l'Ést du Cuanza, dans une direction sensiblement Nord-Sud, visibles dans une grande extension entre les parallèles 11° et 13° de latitude Sud, reposant sur les grès tendres et recouvertes par les sables superficiels.

La première, à l'Ouest, limitant la vallée du Cuanza, a été suivie sur 35 kilomètres, mais probablement doit se prolonger vers le Nord, si elle forme, comme nous pensons, les chûtes du Luando.

Sa direction générale est N-20°-W et la puissance maximum observée a été de 40 mètres à Cuemba, formant une chûte qu'on voit à la fig. 1. Cette intrusion repose partout sur les grès rouges, (fig. 2) ou même violacés, un peu metamorphisés par son contact, se voyant incliner vers l'Èst de 15° à 25°. 20 kilomètres à l'Èst, dans la vallée du Cuziri, la dolérite affleure encore, complètement altérée, ce que nous fait admettre une expansion de la même nappe.

La seconde grande intrusion, à peu près au méridien 21° de longitude E., fait son apparition du Nord au Sud, respectivement dans les vallées du Txiumbo (fig. 3), Cassai, Luêna Lucússe, Lungué-Bungo, et Lucônha, dans une direction générale N-25°-W et sur 240 kilomàtres d'extension.

Dans la figure 3 la chûtte supérieure de 40m, se fait sur la roche volcanique, tandis que la chûtte inférieure nous montre les grès metamorphisés dans une puissance de 6 mètres et plongeant 20° vers l'Ouest.

Au Cassai, un peu en amont du passage de la route Moxico-Saurimo, quelques affleurements traversent le lit de la rivière, mais 20 kilomètres en aval le même grès s'y trouve.

Au Luêna, la nappe forme une petite chûtte de 10 m. d'hauteur, mais on ne voit pas de roches sédimentaires à la base.

Finalement, au Lungué-Bungo, on la trouve sur une aire plus étendue, limitée à l'Ouest par les rapides de la Lucônha (30 kilomètres à peu près); ici, pour la première fois, elle est en contact, à l'Èst, avec les gneiss et se présente, exceptionnellement, recouverte par une couche gréseuse métamorphisée en partie.

La roche est identique dans les deux intrusions, c'est une dolérite de texture ophitique rette, couleur gris-violacée, mais généralement verdâtre, donnée par une substance chloritique. Le feldspath est plus ou moins idiomorphe.

Quelquefois, peut-être dans la partie supérieure de l'intrusion, la roche est très irréguliére, franchement amygdaloidale, avec des amygdales revêtues de cristaux de quartz et zéolithes.

Ces intrusions de dolérites appartiennent probablement à la seconde phase de la grande période d'activité volcanique qui s'est manifestée en Afrique du Sud, à l'époque du Karroo et que, suivant PARKINSON (9) doit succéder à bref intervalle aux épanchements volcaniques du Stormberg, représentés en Angola par la série volcanique du Haut Zambèze, de qui nous reparlerons.

Age de la Série des Grès Tendres.

Malgré les nombreux travaux sur la géologie du bassin du Congo, nos confrères belges n'ont pas encore établi la vraie position du Lubilache en rapport au Lualaba: ainsi, tandis que quelques auteurs les considèrent comme deux faciès d'une même formation, d'autres les croient superposés.

Et cela est d'autant plus embarrassant, si nous remarquons que d'un côté et d'autre il y a des noms de géologues qui se sont familiarisés à la géologie congolaise par de longues reconnaissances sur le terrain.

M. CORNET, qui a créé le système, est d'avis qu'il y a superposition, M. ROBERT la croit "démontrée à l'evidence (10) par le sondage de la Lunwe de M. RICHET, et finalement M. FOURMARIER (11) l'admet aussi en supposant un coincement du Lualaba vers l'Ouest. Cependant d'autres géologues croient plutôt qu'il y a passage latéral d'un faciès gréseux occidental au faciès argilleux oriental.

Les fossiles qui ont été trouvés dans le système du Lubilache, dans la confluence de la Bushimai et du Lubilache, et dans le Kitari, sont des espèces différentes de *Esthèria* et des *Ostracodes.* La première, étudiée par Dr. ULRICH, "paraîssant appartenir au genre *Esthèria,* semble distincte de toutes celles qui ont été décriptes"; la deuxième, de Kitari, est différente des *Esthériella* des couches du Lualaba et ne peût servir à établir un synchronisme entre les deux formations (13);

Une assimilation a été aussi faite du système du Lubilache soit au Cave Sandstone du Karroo, soit au Forest Sandstone de la Rhodésie du Sud. Bien qu'une *Esthèria, Cyzicus draperi, Jones and Woodward,* se rencontre dans le Cave Sandstone, nous avons vu précédemment que les espèces du Lubilache sont des formes nouvelles, et ce genre n'est pas connu au Forest Sandstone.

Dependant les deux formations du Sud sont caractérisées par la présence des réptiles (dinosauriens) et on ne les trouve pas au Lubilache.

Au point de vue lithologique, M.M. DU TOIT et MAUFE sont partisans d'une origine essenciellement éoliènne, tandis que le Lubilache, est lacustre.

Finalement nous avons à l'Est du Zambèze, une série sédimentaire, dont nous reparlerons, qui par sa position et analogie lithologique, semble bien représenter l'Escarpement Grits et Forest Sandstone, diffère nettement des grès lubilachéens qu'on trouve à l'Ouest, tout près, dans le Cassai.

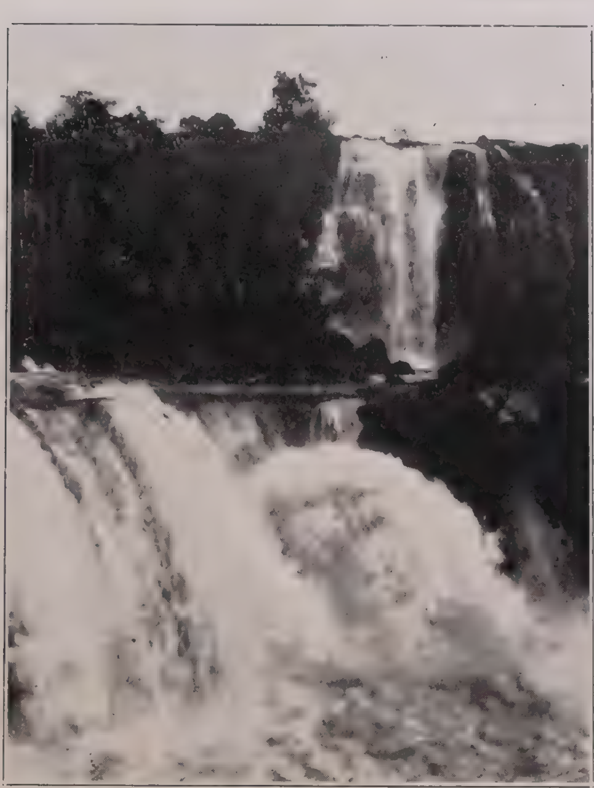

Fig. 3.

Fig. 4.

Cliché T. Aguiar

Fig. 3. Dolerite intrusive (partie superiéure) dans les grès tendres (partie inferiéure)—Txiumbo—Lunda.
Fig. 4. Conglomérat de Pungo Andongo.

Si les dolérites intrusives dans les grès, appartiennent vraiement au groupe des dolérites post-Karroo, ceux-ci restent dans le Stormberg, et on est porté à admettre: soit deux faciès pour les formations qui se rattachent au Bassin du Congo et du Haut Zambèze, soit deux formations d'âge différent.

Distribution géographique et téctonique.

Le système des grès tendres couvre une aire de plus de la moitié de notre Colonie: dès les frontières des Districts du Congo et Lunda, ayant les caractéristiques des formations congolaises, se continue vers le Sud et l'Est, reposant soit sur le Kundelungu, soit sur le socle cristallin qui affleure dans les nombreuses et profondes vallées tributaires du Congo.

Cependant, les formations ne se trouvent pas limitées au Sud, comme on le supposait jusqu'ici, par les roches anciennes formant la dorsale benguellienne.

Les grandes altitudes qu'on trouve à l'Ouest du Cuanza, dans les hauts plateaux du Bié, au-dessus de 1600 m., ne se prolongent pas vers l'Est, entre cette riviére et le Zambèze: le terrain y est constitué par un épais manteau de sables superficiels, laissant voir parfois au fond de quelques vallées les couches gréseuses, les roches cristallines n'apparaîssant que dans ces deux limites.

De l'autre côté du Zambèzè, les traits orographiques ont une direction générale tout à fait différente, NE-SW, atteignant exceptionnellement l'altitude de 1650 m., mais la constitution géologique n'est pas la même, n'ayant rien à voir au socle ancien.

On voit alors que la dorsale benguéllienne ne se prolonge pas à l'Est du Cuanza et la ligne de faite du Congo et du Zambèze, atteignant le maximum de 1530 m., se réduit parfois à quelques mètres de largeur; des altitudes encore élevées se continuent vers le Sud, dans les crêtes du terrain, comme par exemple on voit dans la coupe N-S., tout près de Cangamba, 1424 m., descendant rapidement vers le fond des vallées (Cubangui, 1190 m.)

Cependant la différence de côtes, des couches gréseuses (voir la même coupe), nous montre que nous sommes déjà sur le flanc Sud d'un large anticlinal.

Comme il a été déjà dit, il est impossible de faire une séparation lithologique dans les roches qu'on trouve dès la Lunda, jusqu'à Cangamba et Haut-Cuanza; il faut même remarquer qui elles ont encore une grande analogie à celles qui nettement fluviales, se rencontrent dans le Sud, dans les vallées des tributaires du Kalahari (Okavango, etc.)

On sera porté à admettre une liaison du lac congolien à la cuvette du Kalahari à l'époque du Lubilache?

C'est un grand problème à préciser, cependant nous ne pouvons pas laisser de remarquer:

a) La présence des dykes de dolérites aux limites Ouest et Èst de cette zone, orientés dans une direction à peu près Nord-Sud, qui est une direction téctonique du Continent Africain, pourrait permettre de supposer un éffondrement?

b) Le développement des sables, rouges et blancs, superficiels, un peu argilleux, qui atteignent 240 m. de puissance.

c) La présence au Sud du parallèle 11° d'affleurements de grès tendres toupours dans les cours d'eau, et jamais à des niveaux supérieurs, seulement compacts quand ils sont métamorphisés par les dolérites.

d) Dans la partie du Haut Zambèze, où il change brusquement de direction, à la confluence du Txifumage, fait sont apparition dans les rives ou formant des petits rapides, une roche siliceuse différente de toutes les variétés de grès polymorphes qu'on a rencontrées jusqu'ici, même sur le Zambèze. C'est un quartzite, d'une couleur verte caractéristique, que plus au Sud on voit cimenter un conglomérat de roches qui affleurent de l'autre côté de la rivière, (gneiss et roches sédimentaires).

e) D'après M. du Toit, les dépôts inférieurs du Kalahari, sont constitués par un grès tendre, calcaire, dont la partie inférieure peut devenir un grès plus grossier, grit ou même un conglomérat. Sa puissance n'est pas encore bien précisée, mais peut atteindre quelques centaines de pieds, et doit former une nappe continue, bien qu'on trouve seulement dans les cours d'eau ses affleurements.

L'importance stratigraphique de ces dépôts est grande et son accumultion doit avoir eu lieu dans une période assez longue; les espèces fossiles trouvées aux "chalcedonic quartzite," sous les sables rouges supêrieurs, appartiennent déjà, soit à l'Éocène, soit au Crétacé supérieur (Newton). Étant établi que le Kalahari n'a plus ét envahi par la mer depuis le Jurassique, le commencement de la déposition ne pourrait pas avoir eu lieu dans le début de cette époque?

f) L'analogie constatée dans les formations fossilifères du Mont Bunza, de Cassanje, aux formations des "chalcedonic quartzite" de la Rhodésie.

De reste, l'extension Nord du Kalahari, jusqu'à l'Angola, a déjà été prévue par différents auteurs, et sa limite, suivant Fourmarier, ([14]) devait "s'arrêter à la retombée Sud d'une large zone anticlinale passant par le Benguella." Studt ([15]) dans son "Geological sketch map of Equatorial and Southern Africa" est aussi d'avis à cette liaison, bien que l'âge donné par lui, Waterberg, ne soit le veritable comme il est très bien demontré déjà.

Conglomérats assimillés.

À l'Ouest de la zone lubilachéenne se trouvent deux conglomérats, qui par leur position stratigraphique, sur le Kundelungu, peuvent être synchronisés à la base du Lubilache. Ce sont:

Le conglomérat du Pungo Andongo.

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Fig. 5.

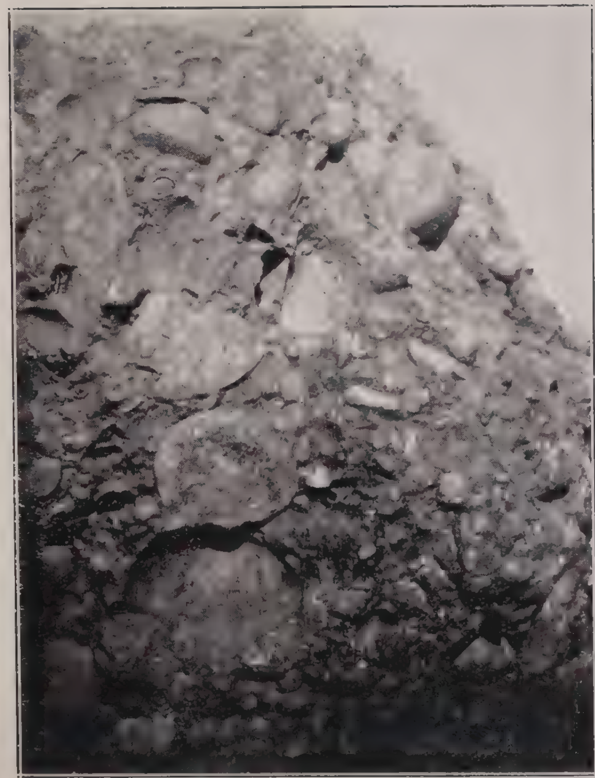

Fig. 6.

Fig. 5. Conglomérat de Pungo Andongo.
Fig. 6. Conglomérat de Pungo Andongo.

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Dans le District de Malange, une centaine de kilomètres à l'Ouest, isolés au milieu du plateau kundelunguéen, s'élèvent brusquement de gigantesques blocs de 140 m. de haut, qui jadis appartennaient à un même massif rocheux comme le fait penser leur rapprochement. Les fig. 4 et 5 donnent quelques aspects de ces blocs.

Ce dépôt couvre une aire allongée Ést-Ouest, de quelques dizaines de kilomètres carrés et est constitué sur toute sa hauteur par un conglomérat très cohérent et dur, à ciment de grès siliceux, légèrement calcaire, unissant des éléments généralement bien arrondis, quelquefois sub-anguleux. Les roches des blocs sont dans la plupart des quartzifes et des gneiss et leur étude parait prouver qu'ils proviennent du Sud; rarement on trouve de petits cailloux empruntés aux couches du Système Schisto-Calcaire.

L'énormité de ce conglomérat fait penser à l'intervention d'une action glaciaire, mais les stries trouvées sur quelques blocs ne sont pas très nettes. Néanmoins deux arguments pourraient être présentés en faveur de cette origine: l'absence complète de stratification et le fait que la déposition des éléments n'a été soumise à aucun classement, les petits cailloux et les gros blocs, jusqu'à 60 cm., se trouvent intimement mélangés, fig. 6.

Comme M. du Toit [6] remarque pour la tillite du Dwyka, à Pungo Andongo on voit aussi des fractures planes traversant le ciment aussi facilement que les eléments du conglomérat.

Sensiblement dans le même alignement, s'élève 15 kilomètres à l'Est, un groupe de nombreux monolithes identiques et si hauts que les premiers ce que nous amène à supposer qu'on a affaire à une moraine frontale d'un glacier descendant du Sud, là où se trouvent les hauts reliefs du pays.

Le conglomérat du Bié.

Dans la vallée du Cuito, à Bié, formant un degré plus ou moins continu, d'une puissance variable entre 20 et 30 mètres, on trouve un conglomérat reposant soit sur des argillites rouges du Kundelungu, soit sur les gneiss.

C'est un conglomérat à ciment argillo-gréseux, formé de grains de quartz et feldspath, plus ou moins altéré, variables de dimensions, mais en général grossier; les dimensions et l'arrangement des blocs est le plus variable, atteignant un mètre, roulés, sub-anguleux, applatis même, ayant seulement les arètes arrondies.

L'eau de imbition altère non seulement le ciment mais presque toutes les roches des blocs; cependant, on voit que la plupart sont les roches de la région, gneiss, quartzites du type ancien, quartz et quelqu'uns de roches non connues, roches basiques, grès rouges, etc.

Aucun bloc a montré vestiges de glaciation, seulement un, d'un gneiss fin, ques nous connoissons de la région, présente un aspect curieux, et dont la forme nous ne savons pas expliquer.

Age.

Dans les descriptions que nous venons de faire, nous voyons qu'aucune certitude d'une origine glaciare éxiste. Cependant, on sait que au début du système Lualaba-Lubilache, au pourtour du bassin du Congo, des conditions glaciaires régnaient incontestablement à l'Èst et au Sud-Èst (Maniema) et aussi au Sud-Ouest.

Dans l'Angola Mr. ROBERT (17) a déjà admis la repercussion du phénomène, "en attribuant à une action glaciaire l'apport des blocs et cailloux de le vallée du Lui, quoiqu'il n'a pas observé de stries glaciaires." Dans un autre travail (10) ce géologue suppose que les glaciers du Sud-Ouest devaient venir des hauts plateaux du Bié; là justement, à une altitude de 1635 m., existe notre conglomérat.

II. SYSTÈME DU HAUT ZAMBÈZE.

Constituant une région de relief assez important toute la rive gauche du Haut Zambèzè présente une modification dans notre territoire, d'une monotonie frappante à l'Èst du Cuanza.

Ainsi, deux grandes lignes d'hauteures, sensiblement parallèles, orientées NE-SW, la traversent, la plus importante à l'Èst et atteignant des côtes aussi élevées que 1650 m., et les deux de constitution géologiques différentes: la première, à l'Ouest formée de roches sédimentaires et la seconde de roches volcaniques.

1. ROCHES SÉDIMENTAIRES.

Stratigraphie.

Limitant la vallée du Zambèze, 50 km. à l'Èst, on voit une falaise plus ou moins abrupte donnant accès à une région de niveau plus élevé.

Cette falaise peut être formée soit par des roches gneissiques, ayant à la partie supérieure les formations sédimentaires, soit complètement par celles-ci, vers le S.W.

Jusqu'à la base des roches volcániques, 20 km. à peu prés, elles affleurent régulièrement, devenant plus rares après, en n'y voyant en général que des sables, exception pour les cours d'eau où affleurent les formations anciennes.

La puissance est variable, ainsi dans l'extrème NE, tout près de la frontière, nous avons mesurée 20 mètres, mais le terrain s'élève encore vers l'Èst; un peu plus au Sud, dans la vallée du Luizavo, qui forme des chûttes en traversant la falaise, a donné le maximum de 110 mètres, qui se maintient vers le Sud.

Dans ce groupe de formations, nous distinguons des conglomérats et grès grossiers, des grès et quartzites et des schistes compacts.

Les conglomérats ont été vu seulement en deux places, dans les deux côtés de la formation volcanique, ayant à l'Ouest la puissance de 20 mètres; les blocs ont parfois 15 cm., principalement du quartz et des quartzites englobés dans un ciment compact de grès grossier feldspathique.

Les grès et les quartzites, nous les considérons ensemble parce qu'on les rencontre dans les mêmes affleurements (les quartzites peuvent très bien résulter de l'endurcissement des grès, ou les grès de l'altération des quartzites), sont la formation plus puissante.

Ces couches, constituent la falaise proprement dite, en moyenne 40 à 60 mètres.

La roche est à grain fin, jusqu'à un millimètre, presque toujours feldspathique, et on voit dans la masse de grains plus arrondis revêtus d'un film rouge d'oxides de fer. À l'approximation des roches volcaniques, dans la Lupéu (route de Calunda), et dans la Luhéhe (au Sud), le grès est différent: tendre, argilleux, micacé, rouge et présentant des taches irrégulières d'argilles. Cependant, dans la même route de Calunda et à 500 mètres seulement de la base des roches volcaniques la roche est encore un quartzite fin.

Les couches, sont parfois puissantes, s'y voyant très bien la stratification irrégulière, croisée, et ripple marks.

Les schistes, qu'on ne trouve pas au Nord de la route Cazombo Calunda, mais qui se dévelloppent au Sud jusqu à atteindre 50 mètres se reduit ici à une couche sur les roches antérieures.

La roche est compacte, quelquefois plus argilleuse, schisteuse, quelquefois presque un quartzite, de couleur variant du jaunâtre, verdâtre au lie de vin.

2. Roches Volcaniques.

C'est une bande orientée aussi NE-SW, visible dans 140 kilomètres de longueur et 25 kilomètres de largeur, ayant la pente Ouest plus rapide.

La formation présente une puissance maximum de 320 mètres au Nord de Calunda, atteignant l'altitude de 1050 mètres, mais cette valeur déscend à 170 mètres à Calunda même; entièrement constituée par des roches volcaniques, forme une série de coulés de laves, au moins cinq, mais peut-être plus, et on n'y voit des roches sédimentaires interstratifiées.

La roche, qui n'a pas été encore examinée au microscope, est une roche volcanique, (basalte?) parfois microscristalline parfois à texture ophitique, parfois très amygdaloidale (surtout à la division des coulées), ayant du quartz, de la calcite, de l'épidote, des zéolithes, de la pyrite, chalcopyrite, etc.

La composition est très régulière, ainsi, dans l'extrème so où nous avons vu une puissance plus réduite, 145 mètres, est identique encore; la formation se présente ici plus nettement en gradins, qui forment parfois des parois verticales de 45 mètres, atteignant l'altitude maximum de 1400 mètres. Et les roches volcaniques semblent finir ici, parceque on ne voit au delà de la frontière ce relief si caracteristique.

Téctonique.

Les formations sédimentaires que nous venons de signaler, semblent occuper un sinclinal dont la direction est NE-SO, direction générale des accidents téctoniques de la région limite du Congo Belge (plis luàlabiens).

Elles se terminent brusquement à l'Ouest, sur les roches anciennes, formant une falaise presque continue dans la direction indiquée, variant de N-20° à 65°-E mais la moyenne de N-30°-E, dont l'origine peut très probablement être attribuée à une faille.

Il est intéressant de remarquer, en faveur de cette hypothèse que:

(a) on trouve dans les extrèmes NE et SO, tout en bas de la falaise, sur les roches anciennes, quelques affleurements de roches sédimentaires qu'on rencontre en haut (quelquefois 100 m. de différence de niveau).

b) la forme d'une falaise plus ou moins continue, qu'on ne voit plus à l'Èst des roches volcaniques.

c) la présence au Zambèze (Cucula) d'une source thermale.

Les formations sédimentaires plongent presque partout vers le SE, avec des inclinaisons faibles, 11° à 15°, et semblent concordantes, au moins dans cette première reconnaissance.

On ne les voit pas en contact directement avec les roches volcaniques, seulement au Sud, la petite colline qui s'élève dans la rive gauche du Luhéhe, semble montrer que la première coulée les a traversées, entre les grès qu'on trouve à la rive droite, au niveau de la rivière, et les schistes du haut de la colline qui se trouvent métamorphisés.

Âge.

Bien que l'examen au microscope ne soit pas encore fait, la description que nous venons de faire de la série vólcanique, semble permettre de les considerer comme appartennant à la même série des éruptions basiques de la Rhodésie (Batoka Basalts) et de l'Afrique du Sud "Volcanic-beds" du Karroo supérieur.

Ces laves du Karroo, dont l'extension se limitait jusqu'ici au parallèle 16°, en Rhodésie du Nord, par la découverte de MENNELL ([18]) dans la rivière Cafué, au Nord de Victoria Falls, sont vues maintenant au parallèle 11°, dans une puissance (310 mètres) et extension (140 kilomètres) aussi importantes.

Elles semblent combler le fond d'un sinclinal des roches sédimentaires, dont l'âge doit être en conséquence, et par des analogies lithologiques, assimilées aux couches du Karroo supérieur de la Rhodésie du Sud, probablement représentant les deux niveaux du "Escarpment grits" et "Forest Sandstone" (Stormberg); cependant, la partie supérieure des schistes compacts vient nous embarrasser.

Déjà MENNELL ne voyait pas de discordance dans les formations sédimentaires qui se trouvent au Cafué, supportant les basalts, et les attribuait à

ces deux niveaux, malgré la puissance bien plus réduite que les affleurements plus proches.

Aucun fossil a été trouvé dans ces travaux préliminaires, mais il est possible que nous y trouvons dans les études suivantes qui viendront préciser plus nettement sa position dans l'échelle stratigraphique.

III. Système du Dondo.

Stratigraphie.

Ce système comprend les couches de Quilungo et du Dondo.

1. Couches de Quilungo.

Adossée aux premiers contreforts de la chaine montagneuse qui sépare le litoral actuel de l'ancienne cuvette kundelunguienne, se trouve une formation gréseuse dessinant une étroite bande qui, de Dondo, se dirige vers le Nord-Nordest, sur une centaine de kilomètres. Sa largeur varie de 8 à plus de 20 kilomètres.

La formation est constituée par une série de grès argilleux, qui alternent avec deux importants niveaux de schistes argilleux, également rouges et micacés. Ces couches sont stratifiées en lits minces et épais, ondulant largement.

Les couches de Quilungo rappellent beaucoup, dans son ensemble, les schistes grèseux de notre Kundelungu à Quèlla, mais en différent par les lits de cailloux roulés de quartz, petits et exceptionnellement atteignant la grosseur de la tête.

2. Conglomérat du Dondo.

Celui-ci se trouve à Dondo, encaissé dans une depréssion mesurant 8 kilomètres de diamètre, à peu près, dans les couches du système métamorphique de Cambambe, auxquelles sont presque exclusivement empruntés les éléments du conglomérat: en effet, ceux-ci accusent un transport assez court, ils sont anguleux et même applatis, n'avant subi aucun classement; les cailloux moyens prédominent et les plus grands atteignent jusqu'à 45 cm.

La pâte, de couleur rouge foncé est argillo-calcaire et pétrie de fragments des roches de ses éléments. C'est très remarquable la nature calcaire du ciment, qui, par l'infiltration de l'eau, a donné origine à de veritables nappes d'un tuff calcaire, qui se penchent sur les falaises du canon, que le Cuanza a creusé dans le conglomérat.

Le conglomérat dépasse une centaine de mètres de puissance et s'est déposé un bancs épais qui inclinent légèrement vers l'Ouest.

A sa base, aussi bien que dans les couches de Quilungo, on trouve localisés de petis bassins d'un charbon bitumineux.

Âge.

Le conglomérat du Dondo a été synchronisé à la tillite de Dwicka, de l'Afrique du Sud, mais les blocs striés sont assez rares et peu démonstratifs; nous le considérons à la base des grès de Quilungo, qui doivent être le prolongement vers le Sud des grès sublitoraux du Congo Français et Gabon qu'on s'accorde à placer dans le Trias Supérieur.

Aucun fossil a été trouvé et nous n'avons vu qu'une discordance avec le Crétacé fossilifère (Sénonien); cependant, il est remarquable l'analogie lithologique aux couches de Lui (Mpioka).

Des phonolites, appartenant au groupe volcanique du Cameroun, que M. Holmes admet comme Tertiaires (19), sont intrusives dans la partie supérieure de la formation, soit en dômes, soit en nappes.

IV. Système de Malange (Kundelungu).

Ce système n'est répresenté que par deux niveaux, les schistes grèseux ou couches de Lui et les grès feldspathiques ou couches de Lombe.

Stratigraphie.

1. Couches de Lombe.

Ces couches on les voit au Nord dans la vallée de l'Inkissi (Zadi) et au Sud sur les plateaux de Pungo Andongo et de Malange.

Près de cette ville, dans la vallée du Lombe, les grès sont grossiers et contiennent, outre des cristaux cristaux roulés de feldspath frais, mésurant jusqu'à 15 m/m., des galets de quartz et quartzites fins: la roche présente ainsi les caractères des couches de l'Inkissi de M. Cornet et permet d'établir la liaison aux couches de l'horizon V du système du Kundelungu au Katanga.

Formant les chûttes du Condo, sur le Cuanza, les grès feldspathiques grossiers viennent cimenter un conglomérat compact et dur, à élements mal roulés, ou même anguleux, de roches siliceuses, cherts oólithiques noirs, quartzites fins, rarement dépassant les dimensions d'un oeuf.

Un grès, encore grossier, et à petits cailloux de nature identique, on trouve à la falaise du Cuale, qui limite à l'Èst le plateau du Duc de Bragança. Tous ces éléments sont empruntés aux couches du système schisto-calcaire.

2. Couches de Lui.

La série des schistes gréseux et argilleux du niveau IV du Kundelungu, a été reconnue par M. Robert (17) à la falaise du Quella, de plus de 400 mètres de hauteur, et limitant le plateau de Malange vers l'Èst.

Au Nord de Malange, à Duc de Bragança, dans les chutes du Lucala, d'une centaine de mètres d'hauteur, cette même série est interrompue vers la partie supérieure par un grès fin, cohérent et très dur, et dans cet ensemble on voit bien les couches de Mpioka définies par M. Cornet.

Les couches de Lui forment la plus grande aire du Kundelungu de l'Angola, les grès durs, quelquefois micacés et feldspathiques, étant les plus fréquents et bien réconnaissables; nous les avons trouvés au Nord-Èst de la Lunda affleurant dans la vallée du Luhembe.

Ces grès forment encore au Nord du Congo les chûttes du Mbriz, marquant ainsi l'affleurement le plus occidental et le plus bas, 550 mètres au niveau de la plaine subplanaltique schisto-calcaire.

D'aprés M. Bebiano, le passage du système schisto-calcaire aux couches de Mpioka se fait à la frontière Nord du Congo, près de la Borne 28, par un escarpement de 200 mètres, sur la vallée du Luidi. L'auteur distingue de bas en haut:

Calcaire noirâtre—50 mètres
Brèche grossière à ciment calcaire et éléments pisiformes et pugillaires de silex et calcaires—100 mètres.
Grès et schistos rouges—50 mètres.

Cette brèche, que nous n'avons observé nulle part, doit être la brèche du Niari et du Bangù, et que M. Delhaye et Sluys ([20]) considèrent comme la base des couches de Mpioka.

Les couches de Lui aussi bien que celles de Lombe, présentent de beaux ripple-marks, et dans les premières nous avons constaté le désagregation en noyaux de formes ellipsoidales.

Les couches du Kundelungu dessinent un large anticlinal, dont l'axe Èst-Ouest, sur le parallèle 7°, donne lieu au plateau de Bungo qui atteint les plus grandes altitudes du Congo.

Âge.

L'étude du Kundelungu dans notre Colonie n'apporte pas malheureusement des arguments de valeur pour la discussion de son âge, puisqu'il n'est représenté que par les deux niveaux supérieurs.

Cependant, nous voudrions remarquer ici que les conclusions qui se sont basées sur la probabilité de l'assimilation de la série de Oendolongo, dans le plateau de Benguella, de Gregory ([2]), au Kundelungu (couches de Mpioka), sont douteuses.

D'après la description de nos couches de Lui, le prolongement Sud des couches de Mpioka du Bas-Congo, et qui forment la presque totalité de notre Kundelungu, soit en puissance, soit en extension, elles sont essenciellement schisteuses et argilleuses et n'ayant aucune analogie avec la série de Oendolongo, décripte par l'auteur, plutôt gréseuse.

Bien que nous ne connoissons pas la formation dans le même endroit, mais plus à l'Èst, ce faciès gréseux-quartzitique se maintient, et aucune liaison peut être faite aux couches, qui à peu près dans le même parallèle, se trouvant à Bié, dans la vallée du Cuito, l'affleurement plus au Sud des couches de Lui.

La suggestion de M. Gregory d'un âge bien plus ancien pour la série de Oendolongo, nous semble acceptable puisque nous y trouvons aussi d'affinités à d'autres séries de quartzites, largement répandus dans la région et qui doivent être encorporés dans le substractum ancien.

Malgré l'insuffisance d'épreuves pour la question de l'âge du système du Kundelungu, nous continuons à le considérer dans le Karroo, d'accord avec M.M. Cornet et Robert; le puissant conglomérat glaciaire de la base est un argument de poids, puisqu'il ne se trouve pas à la base, soit du système du Waterberg, soit du Système du Umkondo, auxquels M. Fourmarier ([21]) a aussi assimilé le système.

Distribution géographiques et tectonique.

Le système de Malange s'étend sur une large zone dans les districts de Malange et Congo, plongeant à l'Èst du Cuango sous les grès tendres du Lubilache, pour ne réapparaître que dans quelques vallées.

Au Sud, son extension est connue jusqu'au parallèle 10°-30° passant ici à 25 kilomètres à l'Ouest du Cuanza; un petit lambeau isolé de schistes argilleux se rencontre encore au fond de la vallée du Cuito, à Bié, plongeant 17° vers le Sud-Ouest, recouverts par le conglomérat assimilé à la base du Lubilache. Cet affleurement, à l'altitude de 1635 mètres serait le plus haut connue en Angola.

Le Kundelungu repose au Congo sur le systême schisto-calcaire, mais partout d'ailleurs il surmonte les formations anciennes.

Les couches forment de grands plateaux, parfois profondément ravinnés, dont l'altitude varie de 1,000 m. à 1,400 m., présentant de longues et hautes falaises, dans toutes les directions, mais principalement vers l'Èst; elles montrent leur raideur et un aignement plus ou moins parfait sur des dizaines de kilomètres.

La descente des plateaux se fait souvent par des térrasses successives, et des massifs tabulaires se lèvent au dessu de la plaine environnante, quelqu'uns encore attachés. Ainsi, au milieu de la vaste plaine de Cassanje, on peut même voir à 30 kilomètres environ de la falaise du Quela, un grand massif dont l'altitude égale celle du plateau de Malange et qui doit prouver l'ancienne extension de celui-ci. On peut conclure que ces falaises qui découpent les plateaux kundelunguiens sont dues au travail extraordinaire de l'érosion, ce que n'exclut pas la possibilité des éffondrements dans les parties plus centrales, là où se sont déposées les couches du Lubilache.

V. Système du Bembe (schisto-calcaire.)

Stratigraphie.—

Ce système repose sur les couches métamorphiques du Congo et débute par un concloméral exposé à divers endroits; nous l'avons pu suivre pendant

36 kilomètres, au Sud de Samba-Cajú où il est orienté Nord-Sud, plongeant fortement vers l'Èst.

La pâte, argillo-calcaire, compacte, plus ou moins schistoide, noire, bleuâtre ou verdâtre, est chargée de petits grains de quartz et de feldspath frais.

Les éléments sont disséminés sans aucun classement; les gros blocs atteignant 30 centimètres, sont bien roulés et constitués par des gneiss et des quartzites; des petits cailloux anguleux de calcaire noir (couches de Sekelolo?) y existent aussi.

Ce conglomérat, avec une puissance maximum observée de 20 mètres est le même qui a été décript par M. M. Delhaye et Sluys ([20]), qui lui donnent une origine glaciaire; nous n'avons pas trouvé des stries sur les blocs.

La subdivision en de niveaux régionals n'a pas encore été faite; cependant, nous avons identifié les différents horizons établis par ces auteurs.

Ainsi au Nord, à S. Salvador, le niveau du Bulu a été reconnu par son alternance de calcaires argilleux et de schistes calcareux en bancs minces; sur le même parallèle, le niveau du Luanza est réduit mais celui du Lukunga s'étend largement, bien reconnaissable par les sables blancs et fins, dits "de Thysville." Près du passage aux couches du Kundelungu, se localise le niveau du Bangú caractérisé par le faciès charbonneux et cristallin, à plages spathiques courbes, et par la structure écailleuse ou ondulée de ses calcaires.

Sur notre coupe Ambrizete-Cuango, le système commence à l'Ouest par le niveau de la Luanza, à calcaires gris clair ou gris blanc, massifs, donnant lieu à de grands monolithes abritant des cavernes. Le niveau du Lukunga, succède et le terrain y est couvert de abondants blocs de meulières, que nous avons vu sur place formant une couche. Dans la région du Uiji, le niveau du Bangu est représenté par des calcaires blancs, sacharoides.

Distribution Géographique.—

Le système schisto-calcaire du Bas Congo, se continue dans l'Angola par une bande de direction générale N.NO-S.SE., jusqu'au parallèle 9°; un petit lambeau de puissantes couches de calcaires fétides, du niveau du Bangú, reste isolé au milieu du Kundelungu, à Cacòle, près de Malange.

Âge et Téctonique.—

Bien que cette première étude du système schisto-calcaire dans l'Angola n'apporte pas des arguments en faveur ou contre son inclusion dans le Kundelungu, il est util de remarquer quelques faits importants:

a)— la discordance qu'on peut déduire de l'examen de l'esquisse géologique où est représentée allure générale des plis des deux systèmes.

b)— le fait que le Kundelungu s'avance en transgression sur les systèmes plus anciens.

c)— dans la coupe que nous donne M. Bebiano à la frontière congolaise, la seule qui jusqu'à présent nous montre le contact, il semble y exister une concordance, puisque l'auteur ([16]), nous dit que les couches plongent dans l'ensemble vers N-15°-E.

d)— selon le même auteur, la brèche base des couches du Mpioka, aurait ici une puissance de 100 mètres, valeur bien supérieure à celle qui a été observée au Bas Congo (35 mètres.)

Malgré les analogies que M. M. DELHAYE ET SLUYS trouvent au point de vue lithologique et téctonique avec le système du Transvaal, ces auteurs continuent à considerer le S. schisto-calcaire du Bas Congo dans le Karroo.

Et cette manière de voir, il faut ne pas l'oublier, a été le résultat de l'étude la plus complète et la plus approfondie, réalisée sur une extension si considérable, qui a été faite jusqu'aujourd'hui.

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24. A CONSIDERATION OF THE TERM TANGANYIKA SYSTEM WITH SPECIAL REFERENCE TO UJIJI AND UHA REGIONS.

BY

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BEHREND (1) in a very useful and comprehensive review of East and Central African Geology in 1918 included under the term "Tanganyika System," a series of sediments found at intervals along or near the shores of Lake Tanganyika. They comprise conglomerates, quartzites, sandstones, arkose, shales and limestones, chiefly dolomitic, in part silicified as hornstones and cherts. At that time no fossils had been recognised in these beds and BEHREND regarded them as a pre-Karroo series of continental origin. They show some extensive faulting, no acute folding and generally the strata lie at low angles of dip. Various writers have referred to certain areas in which these rocks occur; a number have attempted a correlation within the Central African and with South African Systems, but considerable divergence of view and uncertainty still exists concerning these rocks and their place in the geological time scale.

Information is steadily accumulating and it is not surprising to find that several distinct systems are represented in the region under consideration. The limited areas traversed by the earlier workers and the hasty nature of many of the journeys naturally provided only an imperfect account of the geological history. If one includes the extensive development of sediments of the upper Congo and of Uganda, an area of probably 500,000 sq. miles is involved, that is more than the area of the Union of South Africa. Notwithstanding the active exploration in Central Africa during the last couple of decades and the rapid progress in geological investigation which has taken place in the last decade especially, there are still many difficulties in correlating, (with little or no palaeontological assistance) sediments over such a wide area. The difficulties are greater still when the formations of the whole of the sub-continent reaching to the Cape are involved.

Of the various geologists who have written about some of these formations the following names may be mentioned:—

Gregory (2), Studt (3), Behrend (1), Dantz (4), Scholz (5), Krenkel (6), Tornau (7), Koert (8), Grosse (9), Robert (10), Cornet (11), and Fourmarier (12). The divergence of opinion regarding the Tanganyika System and its supposed representatives elsewhere may be broadly classified into two groups:—

(a) A Pre-Karroo age.
(b) A Karroo age.
(a) Gregory, Studt, Behrend and Tornau favoured a pre-Karroo age ranging from Waterberg to the Transvaal System.
(b) Dantz, Scholz, Krenkel, Cornet and Fourmarier upheld a Karroo age.

It is now quite certain that both Karroo and pre-Karroo formations do occur within this region and one of the tasks awaiting to be done to classify the situation is to separate the various sedimentary series into their correct stratigraphical positions. No possible correlation especially with South African Systems can be considered until this is attained.

Geological boundaries pay no respect to political frontiers and the solution of this, as of many other geological questions in this region, may well remain unsolved or confused without the active co-operation and opportunity for intercourse between the workers in the respective areas concerned. These are essentially Uganda, Kenya, Tanganyika, Nyasaland, N. E. Rhodesia and the U. Belgian Congo.

Great as the areas and distances concerned are, the facilities for rapid transport by motor, train or even air are so rapidly improving that it is hoped that more and more opportunity will be afforded for the workers in the adjoining areas to meet and discuss common problems in suitable localities.

Often geological workers are striving independently to solve similar problems in restricted areas and many valuable and helpful results could be attained and time saved eventually by such conferences.

It is only proposed in this short paper to review specially a small portion of this vast Central African region with reference to certain rocks, which have been included in the past under the term Tanganyika System.

Before describing these rocks, however, a brief reference to the distribution of certain sedimentary groups round the lake, particularly on the Southern and Eastern sides will be helpful in gaining an idea of the relationship of the area in question to the region generally.

Starting at the Southern end of the lake, its shores from Cameron Bay in North and East Rhodesia round to the North of Kasanga in Tanganyika Territory are bordered by sediments in which hard fine reddish sandstones and sandy shales prevail, which for the time being may be described by the geographical term of the Abercorn and Kasanga Sandstone Series which form bold high scarps overlooking the lake.

Northwards on the East shore extending to beyond Kirando there is an extensive belt of acid porphyritic rocks, about which not much is known, but in part they appear to represent acid lava and consolidated tuffs, older than the foregoing sedimentary formation, for water worn boulders of the porphyry occur in what appear to be basal conglomerates in the Kasanga sediments.

Similar porphyritic rocks occur on the opposite shore of the lake in Belgian Territory where they have a considerable development. On the Eastern side of the lake these porphyries flank to the East hard quartzite and crystalline gneiss and schist, which extend to the great scarp overlooking the Rukwa Rift. Several wedges of coal bearing Karroo sediments have been let into the old massif by faulting and occur on the high ground as well as at the base of the scarp of the Rukwa Rift.

Further north along the eastern side, a highland mass of crystalline rocks extends for about 120 miles. On the western side of the lake opposite to this, F. BEHREND's map shows a long strip of granite for about 100 miles which gives place to the archaean complex extending to within a short distance of Albertville.

Continuing northwards again along the eastern shore from a point about 60 miles south from Kigoma, sedimentary rocks reappear. In the vicinity of the Rugufu River are hard sandstones and quartzites, cleaved and schistose argillaceous beds which suggest rocks similar to the Karagwe-Ankolian System further north.

From the Rugufu northwards to the source of the Malagarasi, thence North-North-East for another 160 miles there is an area which specially comes within the consideration of this paper, for it contains the members of what has been termed the Tanganyika System to be described later as the Uha System. On the western side of the lake from the south of Albertville northwards for about a hundred miles and particularly westward along the Lukugu River similar sediments occur parallel with strips of much older quartzite and phyllite. A mountainous belt of quartzite also comprises the chief rock along the lake north from Kigoma.

Both sides of the lake at the northern end beyond this are shown on BEHREND's map as being composed of Archean rocks. In the northern portion of the Kibondo district quartzite, phyllites and schists occur which are continuous with those of the West Bukoba province and Uganda, belonging to the Karagwe-Ankolian System. The eastern side of these rocks is flanked by a long strip in which sandstones with some sandy shales prevail comprising the Bukoba Series doubtfully correlated with the Abercorn-Kasanga sandstones at the southern end of the lake. Apart from a relatively small area of young sediments of late tertiary age along the lake shore there are within the area under consideration, sedimentary formations of at least 3 distinct ages. It will be seen that in a general way similar formations occur in approximately similar positions on opposite side

of the lake. One notable difference however is the absence on the western side, of the pre-tertiary amygdaloidal basalts of probably Karroo age which cover such a wide area in Uha to the North East of Kigoma.

The Kigoma Series and the Uha System.

It is proposed now to describe chiefly the main features of the rocks which compose the above groups. The total area of Uha System alone is still undetermined, but it probably amounts to upwards of 12,000 square miles, only 8,000 of which have been traversed by the writer, nearly half of which is composed chiefly of amygdaloidal basalt. The area under consideration lies chiefly north of the railway between Kigoma and Malagarasi railway station which line forms the base of an area roughly triangular in shape extending north to a sharp apex reaching nearly to the South-West end of Lake Victoria.

An area immediately to the south of the railway extending along the lower course of the Malagarasi River to its mouth has been admirably described by P. Fourmarier. The succession was worked out independently to the north by the writer, the existence of Fourmarier's route being unknown to him till the survey of the northern area had been completed. It is gratifying to note that in general there is close agreement regarding the succession worked out. Fourmarier's work provides a valuable description of the adjoining area.

For convenience the rocks are divided up into the following groups in order of age:—

Kigoma Series .... Karagwe-Ankolian?

Quartzite, sheared and banded felspathic rocks (may be pre-Karagwe-Ankolian), conglomerate, schist (chiefly quartz- and sericite-schist.)

Uha System .... Upper Karroo?

	Approx. thickness.
1. Malagarasi Series	800 ft.
2. Amygdaloidal basalt, tuffs and tuffaceous sediments	2,000 ft.
3. Limestone (chiefly dolomitic), cherts and shales	500 ft.
4. Red Beds, Red Sandstone and Shales	2,000 ft.

Kigoma Series.

Mr. Gillman, Chief Engineer of the Tanganyika Railways was the first to draw my attention to the existence at Kigoma of ancient conglo-

merates and quartzites showing metamorphic characters not possessed by the typical so-called Tanganyika System. A short visit with Mr. GILLMAN to this area in Feb. 1928 confirmed the correctness of his observations and later work enabled the tracing of these rocks northwards along the lake margin for a distance of some thirty miles where they continue into Urundi Territory, now included under the Belgian Mandate.

The conglomerates are well developed in the hill south of Kigoma bay. The pebbles consist of quartz and fine quartzite set in a quartzitic base with a certain amount of fine magnetite. Their appearance is not unlike the typical banket of the Rand. Fine hard quartzites, often sheared, and associated with the conglomerates are well developed on Muloli hill to the east of Kigoma town. Along the railway line approaching Kigoma station good sections of the quartzite are visible, starting at KM. 1,250.1.

To the east of Muloli ridge on the slope to the Luiche valley, outcrops of the red sandstones and shales of the Red Beds can be seen. It is most probable from observations further north that the junction is a fault line.

Beds probably belonging to the Uha System, also consisting of conglomerates and red sandstone and shale flank the western side of the Kigoma Beds, along another fault line trending northerly parallel with the main faults of the lake shore.

The bold rocky range extending north from the west shore of Kigoma bay consists essentially of the same hard quartzite bounded by north and south faults on the east and the west. On the lakeside small crushed remnants chiefly of the upper red beds of the Uha System are found along the headlands at the base of the range. On the east side, a thickness of upwards of 2,000 ft. of Red beds flanks the quartzite along a fault line.

In the deeply cut valley of the Mbugwe stream, which joins the Shuzi or Beswe river, finally forming the Nzasi, some highly inclined hard sediments dipping E.S.E. at 75 degrees are exposed over a limited distance. They consist of hard purplish shale, olive sandy shale, grey thin-bedded sandy flagstones and dark sandy flagstones. They are indurated but there is little or no indication of dynamic metamorphism. They are different in character and more highly inclined than the soft red beds and are regarded as much older. They may easily represent a higher zone than the quartzite of the Kigoma series and are tentatively included with that group.

The valley of the Nzasi river entering the lake about thirty miles north of Kigoma is most important in that it intersects the quartzite range completely and reveals some key structures regarding the tectonics of this range of mountains.

The Red Beds of the Uha System extend from the lake shore inland for about three-quarters of a mile with an easterly dip up to 25 degrees. They are intersected by a dolerite intrusion on the eastern margin, apparently along a fault junction. Extending easterly from here for about three quarters of a mile again are greenish to light coloured sheared and banded

felspathic rocks resembling sub-acid volcanic rocks, some of which suggest altered tuffs. Some thin acid granitic or aplitic veins are injected. These rocks have not yet been examined microscopically. They appear to underlie the quartzites to the east, but it cannot yet be said whether or not it is a conformable junction.

The quartzite series follows on the east, and succeeds the igneous rocks with a very hard pebbly conglomerate composed chiefly of quartz pebbles in a silicious cement. No pebbles of the underlying igneous rocks have yet been found. At approximately a quarter of a mile east of the contact, a zone of brecciation and shear is very pronounced dipping at 38 degs. to the east. The summit of the quartzite range rises to over 3,000 ft. above the bed of the river which here has cut a precipitous narrow rocky channel. At about half a mile from the eastern margin of the quartzites, another pronounced shear zone is noted dipping at about 18 degrees to the west. These shear zones therefore indicate deep-seated powerful compression which has forced the quartzite range up as an upthrust ridge. The gently inclined Red Beds follow unconformably to the east of the quartzite series.

The Uha System.

The traverse of the railway from Malagarasi station westwards to Kigoma intersects representatives of the various members of this system and though the railway cuttings show some interesting and instructive sections, the true relationship is not clear from this traverse alone. It is necessary to travel far afield to find the various sections which establish definitely the true succession.

As far as the writer's observations have been made, the base of each of the various groups has been determined with the exception of that of the amygdaloidal basalt.

1. *The Malagarasi Beds.*

In this series are included a series of flat lying grey to dark shales exposed in the valleys of the Malagarasi and the Rutschugi rivers in the vicinity of Uvinza, showing a thickness of about 200 ft. They rest directly on the Archaean crystalline rocks which are exposed in the bed of the Malagarasi at the Uvinza Salt Springs.

Above the shale follow conformably coarse to fine reddish-grey sandstones, with pebbly bands and conglomerate in which the pebbles are chiefly quartz. There is a very slight dip of these rocks towards the lake and generally, as seen from the valleys their upper edges from striking scarps and table topped hills exposing a thickness of about 200 ft. of sandstone.

The shales have so far yielded no fossils, but there appears to be no reason why an age older than Karroo should be postulated since the succession appears to be a normal one upward through the sandstones to

the Red Beds. The sandstones are only exposed for a few miles north of the railway line along the Rutschugi valley. Their place is taken by later beds further north. They have, however, a considerable development to the south of Uvinza and along the valley of the Malagarasi below this point. Traces of copper minerals referred to by TORNAU (7) have been noted in joints and bedding planes in the rock in the Sindi valley at 30 miles to the south-east of Malagarasi station.

2. *The Amygdaloidal Basalts.*

These rocks cover a wide area in this region, amounting to upwards of 3,500 square miles and attaining an undetermined thickness of over 2,000 feet. They were first referred to by DANTZ as diabase and diabase amygdaloid, but the extent and relationship to the surrounding sediments were not determined. The area of these rocks has now been traced from the Malagarasie river some few miles east of its entrance into the lake, N.N.E. for at least 150 miles with a width in places of up to 40 miles.

The dominant features of this rock are the extensive amygdaloidal structure, the silica fillings of the vesicles as agate and quartz, siliceous veins of jaspery chalcedonic and glassy quartz of late hydrothermal action penetrating the lava, and considerable interstitial secondary quartz within the mass of the rock as revealed in thin sections.

Further indication of an active siliceous hydrothermal phase is the extensive development of cherts as silicified tuff and various types of siliceous rocks from the alteration of the limestone. There is evidence also that an intermittent explosive volcanic phase following the first outpouring of the lavas persisted into the early part of the succeeding limestone deposition, for mixed calcareous tuffaceous shales and limestones together with coarse pyroclastic rocks occur over a wide area at or near the base of the limestone-shale series. No undoubted vents or pipes have been noted, but breccias with both basalt, chert and limestones fragments suggest the proximity of such in a number of places.

Tuffaceous and calcareous shales and also the typical dolomitic limestones have been noted in several places lying directly on the basalt, notably at a place in the lower Malagarasi valley, about six miles east of the small village of Lugala near the mouth of the Malagarasi, and in the Nyamori hills, south-east of Kigoma. Traces of malachite occur in this region also in the siliceous rock resulting from the late hydrothermal phase of the vulcanicity.

The base of the lavas has not been observed but from the close association of the overlying limestone and shales and of the latter with the Malagarasi sandstones, it would appear to be fairly definite that the volcanic period is contemporaneous with that of the sedimentation of the Uha System but later than the Malagarasi Sandstones and partly prior to, partly contemporaneous with the limestone-shale deposition.

The basalt highland is regarded as a fault block against which the limestones and later rocks are faulted on both the eastern and western sides.

3. *The Dolomitic Limestone, Cherts and Shale.*

These rocks have wide development chiefly along the eastern side of the basalt. They have been almost completely removed from the basalt highlands of Kasulu and Kibondo by denudation. Some notable remnants, however, still remain as previously indicated on Mulega and Nyamori hills. Small blocks occur along the base of the western scarp of the basalt highlands, being let down by faulting, particularly in the Luiche valley.

A very striking feature of much of the basalt country is the vast amount of siliceous debris consisting not only of quartz jasper and agate in the geodes, amygdales and veins in the basalt, but of chert, horny and other types of quartz from the silicified portions of the shales and limestones now removed by denudation.

The limestone varies in colour from light grey to dark bluish grey, lighter shades predominating. It is hard and compact and usually weathers with a rough "elephant skin"-like surface. This is often aided by a notable structure within the rock which when well developed assumes a concentric or "eye-like" form varying from small oolitic or pisolitic structures to that of the size of an ostrich egg. Frequently, however, an analogous structure is also developed which is not spheroidal but roughly cylindrical with an internal irregular lamellar structure not unlike that of *Listhostrotion* but no organic structure has yet been recognised in the rock.

Partial selective or complete silicification is a common feature often extensively developed. Sometimes it is regular forming chert bands within the limestone which weather out in outstanding ridges. The closely packed concentric structures with a diameter up to 4 inches appear to resemble in a remarkable way some of those described and illustrated recently by Prof. R. B. Young* and attributed by him to internal multilateral pressure apparently produced by *dilalation* of the limestones.

On the other hand the features appear to resemble algal structures recognised in some of the limestones of the L. Superior region. More investigation of these features is required.

Several typical outcrops of the massive limestone occur in the vicinity of the railway line, notably at Lugufu where it is burned for lime and it is exposed again in a quarry made for railway purposes about 200 yards south of the railway line at Km. 1,226.1. At the latter place it is a light

* R. B. Young, M.A., D.Sc., "Pressure Phenomena in the Dolomitic Limestones of the Campbell Rand Series in Griqualand West." Trans. Geol. Soc. of S. Africa, Vol. XXXI, 1929.

coloured compact limestone well stratified and suitably jointed for breaking into blocks, admirably adapted for building purposes.

The maximum thickness noted amounts to about 500 ft. in the district to the east of Kasulu. The relationship of the base to the basalt is clear in the Mulega and Nyamori hills where it is seen to overlie the basalt, and in the Manyovu highlands, N.N.E. of Kigoma it is clear that the limestone underlies the Red Beds as shewn in the exposure at the base of the scarp on the western side of the Luiche valley in the Vuga stream in the Mugarama hills, also on the western margin of the same highlands in the Mugabwe valley north of Lusimbe's.

That it is down-faulted against the eastern and western side of the basalt highlands is clearly shown by the section on the eastern side along the base of the Nyakachacha Hills, N.E. of Kasulu and on the western side near Kiangali, just north of the place where the Luiche River emerges from its deep course in the highlands to its wider valley in the lower Luiche sunkland.

Associated with the massive limestone, are thin calcareous shales and argillaceous limestones. Some of the shales are reddish to chocolate coloured; others are grey to olive green. One important outcrop is just south of the railway line at Km. 1,226.1 adjacent to the limestone quarry previously mentioned. Here in an old ballast line cutting, the soft grey shales gave undoubted comminuted plant remains, unfortunately too obscure for identification.

If the basaltic period in this area should be contemporaneous with that of the Karroo of S. Africa, then these plant bearing shales with the limestone and the whole of the Red Beds must be placed in a period of very late upper Karroo well within the Mesozoic and should be Triassic or even later.

Other types of shale usually soft but occasionally partly chertified, occur in widely separated localities on this horizon sometimes grey or fawn coloured but more often reddish to chocolate coloured. The harder chertified remnants often form thin cappings on the basalt of the highlands. This is a special feature of the Kibomdo District.

Evidence of movement and dislocation is clear by the outline of many of these hills which are sometimes table topped, but just as frequently show dip and scarp outline in such relative positions to indicate that both gentle folding and faulting have taken place. The topography seen from the Kibondo Boma illustrates this feature in a striking manner.

The Red Beds.

Under this term are included a series of relatively soft sediments with some harder sandstone horizons. In this group a prevailing reddish to chocolate colour is characteristic though some light to fawn coloured beds occur to a limited extent.

The sandstones are often moderately soft, friable and somewhat argillaceous. This series is best developed in the Manyovu highlands which lie to the north of Kigoma between the sunkland along the western scarp of the Kasulu basalt highlands and the rugged quartzite-ranges bordering the eastern shore of the lake. These beds succeed the limestone-shale-chert series apparently without any break, and no very definite division can be made in many of the sections, the calcareous characters of the beds often disappearing upwards gradually. Elsewhere the development of rather distinct fine chert sandstone and breccia-chert-quartz-conglomerates passing upwards into the normal red beds indicates local interruption in the deposition. Some of the breccias suggest a mingling of pyroclastic and normal fluviatile material. Examples of the latter types of deposit are represented in the beds exposed in the upper portion of Seruhembe, Nyngurube, Kiyungwe hills in the N.W. portion of the Kasulu District and on Mwalie and Fuma Hills, in the S.E. portion of the Kibondo District. It is in an outlying pillar or stack of massive breccio-conglomerate and cherty sandstone on the eastern side of Mwalie that the interesting cavern occurs which forms the burial place of the Sultans of that region.

The Red Beds attain their greatest thickness amounting to about 2000 ft. in the Manyovu Highlands, being more protected from the active erosion they have suffered elsewhere, by the rampart of hard quartzite of the Kigoma series on the lake side.

On the eastern side of the basalt highlands, particularly in the vicinity of Uvinza and in the lower Malagarasi valley below this point, the limestone series with the red beds appear to follow the Malagaresi series without the intervening basalt which is so well developed further west. There is not the same thickness of the Red Beds in this region due to more excessive erosion.

Small but very interesting sections of the Red Beds are exposed along the lake margin both north and south of Kigoma where features due to powerful faulting can be studied. Most of these sections show much crushing and puckering due to strong compression with overfolding and thrusting from the east.

Age of the series.

The work of P. Fourmarier on the western side of the lake in the vicinity of the Lukuga valley appears clearly to justify the grouping of the limestone and red beds with the underlying coal bearing shales in one system.

The observations of the writer in the Ufipa region agree in the association of similar limestone and overlying red beds with the coal bearing beds.

The writings of Bornhardt, Dantz and Scholtz and the personal communications of Mr. Gillman regarding the character of the upper portions of the undoubted Karroo formations in the S.W. highlands of the Territory also confirm the existence in that region of a limestone and succeeding red beds phase.

It appears reasonable therefore in the absence of definite palaeontological evidence to the contrary and in the absence also of any strong unconformity, to regard the Limestone and Red Beds series as belonging to a late upper Karroo development possibly of later age than that developed in S. Africa. At any rate a different facies is indicated, and FOURMARIER'S grouping as Permo-Triassic for this system has much to say in its favour.

In conclusion the following table is suggested provisionally as an attempt to clarify the situation regarding the Sedimentary rocks originally included in the term "Tanganyika System."

1. Karroo (or Permo Triassic)— Uha System		Red Beds Limestone-Chert Series Amygdaloidal Basalt Malagarasi Series
Waterberg?	(1) (2)	Kasanga and Abersorn Sandstone Series. E. Bakota Sandstones.
Transvaal? Karagwe-Ankolian	(1) (2)	Kigoma Series and W. Bakota Series.

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25. NOTES ON THE INVESTIGATION OF THE SPORE CONTENT IN CERTAIN KARROO ROCKS

BY

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The valuable results obtained by the study of the distribution of pollen in quaternary peat and silt, suggested that similar work might be done on the microspore content of coal seams and shales of Karroo age.

This work has only reached the stage of the discovery of convenient methods for the separation of such spores, and these methods were described.

Thin slips of dark shale, probably of Lower Beaufort Age, from Lidgetton, Natal, were placed in Hydrofluoric acid and were found to give a dark organic residue. When this was washed and concentrated with a centrifuge, it was found to contain very characteristic winged microspores.

The vertical and horizontal distribution of these spores must be studied at some later date.

For the investigation of the spore content of coal seams, a new quick and convenient method has been found applicable to some Karroo coals. The coal is cut into small blocks about 5 m.m. square, and these are placed in warm saturated aqueous caustic potash for two or three weeks. The blocks are then washed and treated with a solution of Potassium Chlorate in strong Nitric Acid for a day or two. On transferring to a dilute alkaline solution the coaly material dissolves leaving a residue of spore coats, fragments of cuticle, etc. After washing and concentrating this material it can be well mixed with a standard volume of water and a measured volume drawn off and examined under the microscope.

In this way a qualitative and quantitative estimation of the microspore content of the sample can be obtained. This method opens up the possibility of a considerable advance in our knowledge of the distribution of spores in coal, and of the use of spores content for the correlation of seams.

26. SUCCESSIONE ED ETA DELLA "SERIE DI LUGH" NELLA SOMALIA ITALIANA.

PER

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PREMESSA.

Il PROF. P. FOURMARIER, riassumendo nel 1926 al Congresso di Madrid lo stato attuale delle nostre conoscenze geologiche sul Congo Belga, concludeva affermando l' importanza notevole che assume per la geologia generale dell' Africa lo studio di quella colonia, costituente, in certo modo, una zona di transizione fra il nord e il sud del continente; donde la speranza che nella più perfetta conoscenza di quella possa trovarsi la chiave per un raccordo tra la regione Sahariana e la Sud-africana.

Un compito analogo potrebbe attribuirsi, per certi rispetti, alla regione etiopica, intesa, in larghissimo senso, compresa cioè fra Massaua e Mombasa. All' Etiopia e all' Eritrea appartengono infatti quelle "arenarie di Adigrat," che sono considerate in generale, così dai geologi italiani come da quelli dell' Africa del Sud, il corrispondente settentrionale delle formazioni del Karroo; nella Somalia Italiana coesistono, potentemente sviluppate e largamente diffuse, due formazioni alquanto simili per facies, ma profondamente diverse per età: le arenarie di Lugh, inferiori, e ritenute equivalenti a quelle di Adigrat da un lato a quelle del Karroo dall' altro, e le arenarie di Taleh, superiori, che trovano la loro corrispondenza con formazioni anologhe dell' Hadramaut e dell' Alto Egitto (arenarie nubiane) riferite al Cretaceo; finalmente nella Colonia inglese del Kenya le formazioni arenacee inferiori sono largamente sviluppate e formano una potentissima serie, che in Somalia invece non sarebbe rappresentata se non nei suoi membri più elevati.

In Somalia — come del resto anche nel Kenyaland — depositi fossiliferi francamente marini del Giurassico pare vengano a costituire un preciso limite superiore alla serie arenacea. Qui dunque, come al Congo, una conoscenza più approfondita potrà recare luce sulla interpertazione generale della costituzione geologica dell' Africa; ed ogni contributo diretto ad estendere la conoscenza di tali regioni o i parallelismi tra le loro formazioni e quelle di altre regioni africane assumerà evidentemente un certo interesse.

Il bacino congolese e la regione somala — pur così diversi nei loro caratteri, facendo parte il primo del grande massiccio continentale africano, la seconda della fascia marginale, costiera—hanno inoltre alcuni fossili in comune, che permettono di portare qualche argomento in favore di sincronizzazioni, troppo spesso basate solo sulle somiglianze di facies.

Sono, nel Congo, gli strati di Lualaba, in Somalia le arenarie di Lugh. A questi si aggiungono i calcari oolitici e le marne scistose del Nyassaland e del Tanganyka. Sarebbe prezzo dell' opera stabilire un confronto fra queste varie serie: disgraziatamente pochi (se pur ve ne ha alcuno) sono i geologi che posseggano una esperienza personale relativa a tutte queste formazioni, e il confronto allo stato attuale delle cose, e forse per molto tempo ancora, non può essere fatto che su basi bibliografiche.

Per parte mia, io posso contribuirvi soltanto per quanto riguarda le formazioni della Somalia, note col nome di serie di Lugh: le quali sebbene già entrate nella letteratura per opera degli esploratori italiani una trentina d' anni fa, sono rimaste finora a quello stadio assai primitivo, mentre meritano un esame più particolareggiato e minuto, quale mi è consentito di fare in base a dati raccolti durante le due missioni da me espletate in Somalia nel 1913 e nel 1924.

La serie delle " arenarie di Lugh " fu già rilevata da Maurizio Sacchi, meteorologo della seconda spedizione Bottego, nel 1895; ed egli ebbe anche fin d' allora la buona sorte di rinvenire in quegli strati alcuni fossili, poco numerosi ma significativi, i qual permisero al De Angelis (1) (che studiò poi quei materiali, fortunatamente recuperati dopo la eroica fine della spedizione) di affermarne l' età triassica.

Nel 1913 il Prof. Paoli, entomologo della Missione da me diretta, potè spingersi fino a Lugh, e ne riportò numerosi campioni di rocce e dati molto diligentemente raccolti, che furono da me interpretati ed utilizzati (2.)

Finalmente nel 1924 potei io stesso recarmi a Lugh (3), e la presente memoria è destinata appunto a riassumere brevemente quanto mi fu dato osservare a proposito di questi interessanti depositi, coordinando le mie osservazioni con quelle dei miei predecessori e coi resultati di un nuovo esame dei materiali dello stesso Sacchi, conservati nel Museo Geologico di Roma.

Con tutto ciò non poche nè lievi lacune rimarranno da colmare anche nel limitato campo della Somalia: chi ha fatto della geologia nell' Africa Equatoriale non stenterà a comprenderne i motivi.

La Serie di Lugh.

La formazione di cui ci occupiamo è stata da me indicata col nome di " serie di Lugh " perchè bene sviluppata nella regione attorno al villaggio di questo nome, posto su un meandro del fiume Giuba, a 3° 47' 40"

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Fig. 1. La pianura del Giuba presso Lugh e le colline testimoni.

Lat. N. e 42° 33' 44" Long. E. Gr., a circa 330 Km. in linea retta dalla costa dell' Oceano Indiano. La valle del Giuba, che tanto a monte quanto a valle si restringe in gole profonde e quasi impervie, determinate dall' affiorare dei calcari giurassici, qui in corrispondenza di Lugh si allarga in una vasta, bassa pianura, su cui si elevano, isolatamente, colline — testimoni (Fig. 1) residui di un processo erosivo evidentemente molto intenso e molto prolungato.

Così agli ostacoli di carattere logistico, cui ho accennato e che all' epoca del mio viaggio erano più gravi assai che oggi non siano, e alla mancanza di carte topografiche a scala sufficiente, si aggiungono nel caso presente le difficoltà di rilevare profili geologici, in una regione pianeggiante, sprovvista di spaccati naturali un po' estesi, e coperta in gran parte di depositi detritici eluviali o alluvionali e di vegetazione.

Questo tipo di morfologia in un con la posizione quasi indisturbata, ostinatamente orizzontale, degli strati, rende evidentemente necessario uno studio frammentario della stratigrafia, il rilievo cioè di un buon numero di sezioni parziali, dal cui coordinamento e raccordo può solo resultare la serie.

Io mi asterrò tuttavia, per semplicità, dal riportare qui le singole sezioni e dall' esporre il minuto e paziente lavoro analitico, onde resulta il tentativo di sintesi che sto per esporre, e passerò senz' altro ad illustrare una sezione ideale, schematica, della intera serie, rimandando per maggiori particolari ad altro lavoro, da pubblicarsi in separata sede. Accennerò soltanto che la sezione ideale che presento è il resultato del raccordo di tre distinti spaccati. Uno di questi fu da me rilevato nelle immediate vicinanze di Lugh, a Hele Scid e a Dolo Godut: esso corrisponde a quello già sommariamente descritto dal De Angelis, in base ai campioni raccolti dal Sacchi, e si ripete in parte in parecchi punti della regione: nelle colline Goudère e Curetca (Paoli) nei M.ti Afmedòu e Agghерràr (Stefanini), nei M.ti Corèi e nelle valli dell' Ueb e del Daua (Sacchi — De Angelis.) Il secondo spaccato è quello del M. Gurràn, rilevato da me e corrispondente a serie rintracciate parzialmente a Dolo Godut stesso, al Curetca ed inoltre a Godobèi e Boràn Rahmàd (Paoli): alcuni suoi termini figurano pure rappresentati nelle collezioni del Sacchi dei M. Corèi, Ueb e Daua. Il terzo speccato resulta dai materiali raccolti dal Paoli a Gòndar e a Ferdadale, corredati da un profilo da lui accuratamente rilevato, e si completa in alto con materiali e dati raccolti dallo stesso a Marilè e a Carìa.

Il raccordo di questi diversi speccati non è facile a farsi con precisione, data la scarsità di fossili e il ripetuto alternarsi di strati litologicamente simili; però, come vedremo, la serie sedimentare muta i suoi caratteri complessivi in modo netto e progressivo; onde la successione non sembra possa essere diversa da quella da me stabilita. Esistono d' altra parte alcuni orizzonti caratteristici, singolari, che forniscono per le sincronizzazioni preziosi

punti di riferimento. Finalmente una ulteriore conferma sarebbe fornita dal fatto, che i vari gruppi corrispondenti ai singoli spaccati parziali si susseguono, topograficamente, lungo il Giuba, nell' ordine da me indicato, al più alto succedendo (sempre topograficamente) i livelli del Giurassico fossilifero facilmente databili per le loro ricche faune marine; mentre lungo una sezione ortogonale (Ovest — Est) la stessa successione si riscontra, con dislivelli altimetrici tali, che (data la sensibile orizzontalità degli strati) il concetto di una successione stratigrafica ne è parimente confermato; ed anche qui ai termini più recenti della serie succedono i calcari del Giurassico, formanti il tavolato dell' altipiano di Uegít e di Uddùr.

Ciò premesso, passiamo senz' altro a una disamina complessiva dei vari gruppi, onde la "Serie di Lugh" può ritenersi costituita. Ma prima di tutto, una avvertenza circa la base.

La Base.

In nessuno dei punti visitati da me o dai miei predecessori Sacchi e Paoli, i membri inferiori della "serie di Lugh" vengono in contatto col substrato, per modo che non è possibile dire, a tutt' oggi, su che cosa questa formazione riposi. Tanto a levante quanto a mezzogiorno e a ponente (come si è accennato) essa viene in contatto con la serie giurassica marina (serie di Bardera): la quale più a sud, dove essa entra alla sua volta in contatto col substrato, è largamente trasgressiva e riposa direttamente sui graniti. E lo stesso sembra accadere a ponente, dove il Sacchi, risalendo il corso del Daua, ritrovò del pari i calcari giurassici immediatamente sovrapposti al granito.

Questo stato di cose potrebbe avvolorare il sospetto, che i rapporti fra la serie arenaceo-gessosa e quella calcarea del Giurassico siano ben diversi da quelli finora supposti; ma la presenza di fossili del Retico alla base di quella sembra motivo sufficiente a troncare ogni dubbio.

1. Gruppo di Helle Scid.

In complesso, il carattere litologico di questo gruppo inferiore di strati, che affiora appena per una ventina di metri di spessore, può dirsi *arenaceo-gessoso-salifero*. Essa s' inizia con alcuni banchi di arenarie bene stratificate, grigio-verdastre o biancastre, affioranti direttamente nelle sponde stesse del Giuba (Fig. 2), che si fanno più su screziate di rosso e verde od uniformemente rosso-vinaccia, e passanti in alto a marne arenacee fogliettate sempre versicolori, con lenticelle di gesso e abbondanti efflorescenze di sale (Fig. 3.) Il gesso costituisce, più su un banco continuo, di colore grigio o con chiazze verdi, azzurrastre, rosse, per dar luogo nuo-

Fig. 2. Le arenarie variegate con *Colobodus* cfr. *maximus* di Hele Scid (Lugh).

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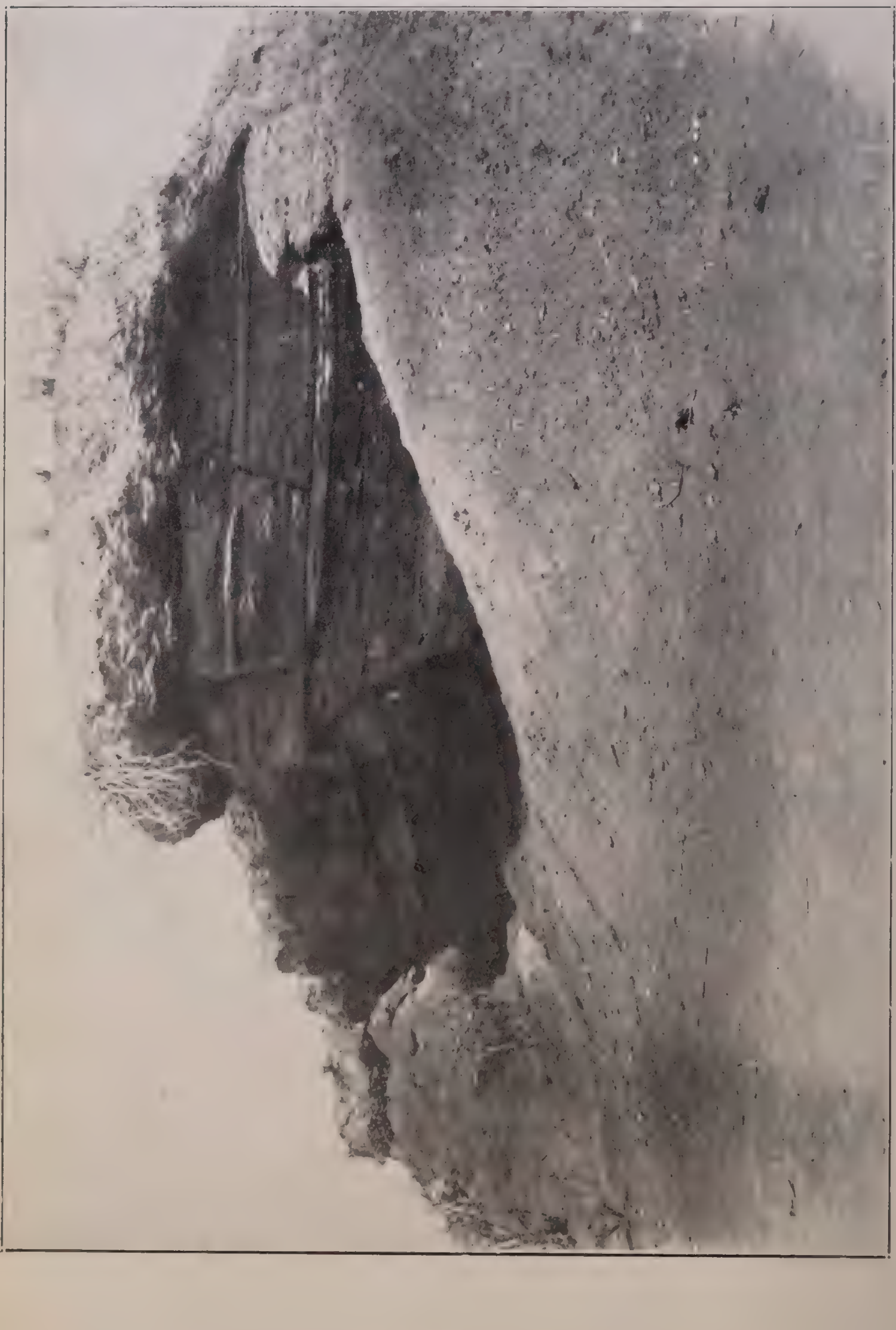

Fig. 3. Marne arenacee fogliettate versicolori con gesso e sale di Hele Scid (Lugh.)

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vamente ad arenarie e marne variegate, passanti lateralmente ad argille arenacee rosse a persino a marne arenacee azzurrastre o screziate o brune, che hanno a Lugh un uso limitato come pietra da costruzione, e tornano a presentare in alto intercalazioni gessose.

Nella arenarie, a diversi livelli ma specialmente nei più bassi, furono raccolti denti e squammette di *Colobodus* cfr. *maximus* Quenst., tanto dal Sacchi quanto, più tardi, da me. Nelle marne di Lugh, poi, raccolsi denti di *Hybodus* cfr. *minor* Agass.

Dal punto di vista litologico, le arenarie furono esaurientemente studiate dall' Artini (4), il quale le definì arenarie fini o finisssime, molto porose, piuttosto friabili, frolle, generalmente prive di calcare e cementate da un cemento siliceo — argilloso e da un parziale ricrescimento della silice, come certe "arenarie cristallizzate." Tra gli elementi prevale di gran lunga il quarzo, in granuli minuti, uniformi, angolosi, talora ricresciuti; abbondanti sono i feldspati potassici (ortoclasio e microclino), meno abbondanti i feldspati sodico-calcici, più o meno scarsi i minerali pesanti, tra cui prevale anzitutto la tormalina, poi lo zircone; magnetite, ilmenite, granato sono meno frequenti, scarsissimi o addirittura rari muscovite, apatite, ottaedrite, clorite, e (quasi sempre presente) la monazite (5); pirosseni e anfiboli mancano invece, di solito, interamente.

Quanto al salgemma, che a certi livelli si osserva in efflorescenze assai abbondanti nelle marne arenacee fogliettate, va notato che la sua presenza come costituente, non accidentale ma veramente essenziale, della formazione è dimostrata dal fatto, che all' Aggherràr, a una trentina di Km. a N.E. Di Lugh, si hanno alcune saline naturali. (Fig. 4.) Quivi non esistono o almeno non ebbi modo si osservare in affioramento strati di salgemma, ma solo vastissime gessaie. Le saline sono estese incrostazioni di sale, che si formano nel letto di alcuni torrenti, e vengono sfruttate dalle popolazioni (Gherra) le quali ne fanno anche commercio. Non appena tolte, queste croste di sale con grande rapidità si riformano, per salienza di acque; le quali evidentemente sciolgono il sale contenuto in lenticelle nelle marne arenacee, e vengono attratte per capillarità alla superficie come suole generalmente accadere nei paesi semiaridi.

2. Gruppo di Dolo Godùt.

A coronamento dei gessi e delle arenarie gessose di Hele Seid sta un filaretto o straterello sottile di marna dura, giallo — bruna, con dendriti di manganese, che rappresenta un orizzonte molto facilmente riconoscibile e un punto di riferimento prezioso per la sincronizzazione dei vari spaccati. Esso forma su larghi tratti il tavolato della pianura generale, in cui il Giuba ha scavato per una ventina di metri la sua terrazza; è l' "argilla color mattone" raccolta dal Sacchi anche nei M. Corei presso Dolo, e più

a nord, nella valli del Daua e dell' Ueb, dove assume spesso un colore rosso e talvolta un carattere arenaceo, e contiene allora abbondanti piccoli gasteropodi turbiniformi e qualche traccia di bivalvi, di cui una corrisponde abbastanza bene ai caratteri del *Mytilus psilonoti* Quenst.

Del resto anche nelle vicinanze di Lugh e specialmente tra Dolo Godut e Soban Allah lo straterello in questione può rivestire localmente il carattere di lumachella di microgasteropodi turbiniformi e turricolati, mantenendo però sempre il suo colore giallo-bruno e le caratteristiche dendriti.

Ritengo che con questo si possa far cominciare il gruppo di Dolo Godut, il quale è rappresentato nella collinetta isolata di questo nome, (il Dodo Godudo del Sacchi) (Fig. 5), nelle vicinanze stesse di Lugh e in immediata continuità di affioramento con gli strati sottostanti.

Questo gruppo è caratterizzato da una grande prevalenza dei gessi (Fig. 6), i cui banchi soverchiano di gran lunga per potenza ed estensione sia le arenarie variegate che ad essi s' intercalano, soprattutto verso la base, sia specialmente le marne, che in sottili strati formano intercalazioni più in alto. Sono gessi in lastre versicolori, gessi in cristalli commisti a marna o a sabbia, gessi bianchi, finemente cristallini, ecc.

I rigonfiamenti di croste superficiali gessose (i quali accennano verosimilmente alla idratazione superficiale di un primitivo deposito di anidrite) e i fenomeni carsici, come solcature a guisa di karren, ponti naturali, doline di sprofondamento o di corrosione, sono molto communi in questi gessi, i quali affiorano del resto su larghissime aree in tutta la regione, dall' abbeverata di Godobei e dalle falde dei Curetca a Lugh, a Usciacca Gurràn, all' Afmedò, all' Aggherràr, ai M. Corei e fin nelle valli dell' Ueb e del Daua, ove ne furono raccolti campioni dal Sacchi.

Le arenarie che si alternano ai gessi nella parte inferiore della serie non presentano differenze sensibili con quelle sottostanti di Hele Scid, nè per la natura, nè pel colore; le marne poi appariscono in sottili strati e filaretti grigi o color crema, talora passando (in alto) a calcari marnosi o a calcari compatti (Fig. 7), grigi o bruni screziati di rosso, in grande lastre solcate superficialmente da minuscoli karren.

Lo spessore complessivo di questi strati del *gruppo gessoso-arenaceo*, di Dolo Godùt può valutarsi ad una cinquantina di metri.

3. GRUPPO DEL M. GURRÀN.

La serie di Dolo Godùt è coronata da un triplice strato, assai caratteristico e ben individuabile, di un calcare dolomitico grigio scuro o bruno, con struttura cristallina, disseminato a tratti da cavità, generalmente ripiene di calcedonio o tappezzate di cristalli di calcite.

Anche questo orizzonte era stato segnalato dal De Angelis, in base al materiale del Sacchi, nei Monti Corèi, nella valle dell' Ueb, in quella del

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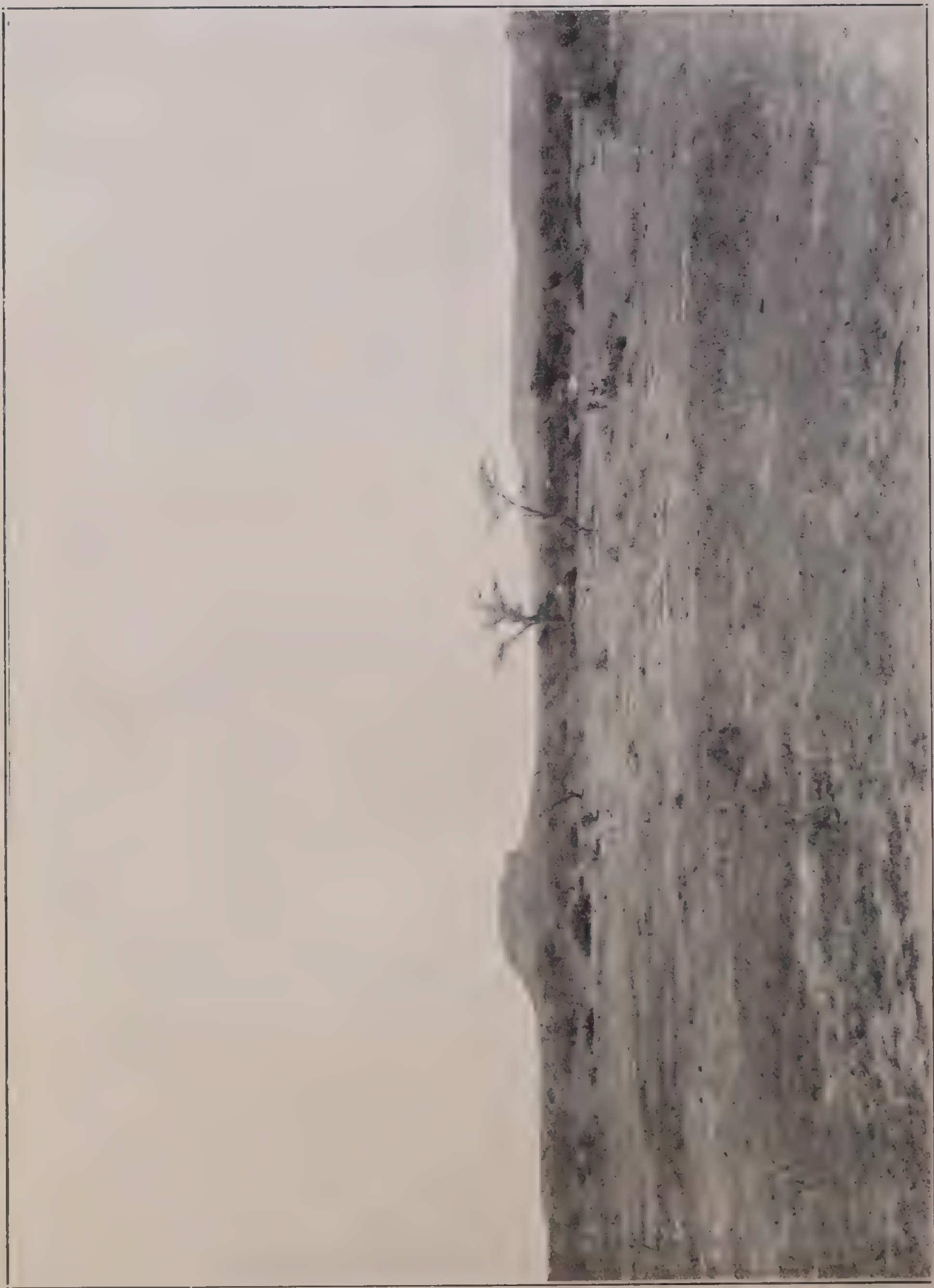

Fig. 5. Collina di Dolo Godùt (gessi e arenarie) e profilo dei Monti Cureta.

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Daua; il Paoli ne raccolse campioni al valico del Curetca ed anche a Godobèi e a Boràn Rahmad lungo il Giuba, 30 — 40 Km. a valle di Lugh. Al M. Guràn esso sembra rappresentato da un calcare dolomitico livido, a chiazze porporine, contenente minuscoli dentini, determinati dal D'Erasmo (in litt.) come *Eugnatus* sp. Prendiamo questo strato come base del gruppo, denominato appunto di M. Gurràn

Il carattere più saliente di questo gruppo, che chiameremmo volontieri *marnoso-arenaceo* (Fig. 8), è quello di un graduale passaggio dalla facies lagunare alla facies marina Sopra la dolomia è ancora una intercalazione delle arenarie variegate, verdi, o gialle, rosse localmente (Curetca), alquanto gessifere verso la base; con qualche interstrato i calcare impuro, giallastro; più in alto però si passa a marne arenacee fogliettate, indi a marne e a calcari variegati, o con lenticelle arenaceo — cristalline, che fanno transizione alla serie sovrapposta.

Questi strati affiorano — a giudicarne dai campioni riportati dal Paoli — anche a Godobei e a Boran Rahmàd, dove sono sormontati da calcari con brachiopodi, pur troppo mal conservati.

Lo spessore totale si valuta a circa 35 metri.

Quanto ai caratteri litologici, osservaremo che le arenarie di questo livello elevato (6) non differiscono, nel complesso delle loro caratteristiche più salienti, da quelle della serie di Hele Scid, e ciò tanto per la natura degli elementi, in grandissima prevalenza quarzosi, quanto per il modo di cementazione, la struttura, l' aspetto: tuttavia è da notare come vi si facciano talvolta abbondanti, insieme al gesso, minerali che sembrano mancare nelle arenarie dei livelli più bassi, e segnatamente un solfato rombico, probabilmente riferibile a barite o barito — celestina.

4. Gruppo di Gòndar (*Marilè*).

La facies calcarea, che si era cominciata ad affermare nella parte alta del gruppo precedente, diviene qui predominante, per modo che il gruppo potrebbe denominarsi *marnoso-calcareo-arenaceo*. Sono, per la maggior parte, calcari e marne grigi, compatti, con dendriti, e lenticelle a struttura minutamente cristallina, che spiccano pel colore bruno o rossastro e per la maggiore resistenza all' erosione, sul fondo chiaro della roccia. Talvolta la parte cristallina prende la prevalenza su quella compatta, e si ha allora un calcare cristallino bruno, con lenticelle chiare, calcareo-marnose.

Nei tipi più marnosi specialmente, accade spesso che le lenticelle siano indicate solo da differenza di colorazione, (rossastra o porporina) e allora essi tendono a confondersi coi calcari marnosi, screziati o striati, che compaions sporadicamente nei Gruppi di Gurràn e di Dolo Godùt; oppure sono evanescenti, appena accennate, e in tal caso la roccia si avvicina alle marne chiare, intercalate pure nella parte più elevata delle serie precedenti.

Caratteristiche di questo livello sono anche le frequenti alternanze di sottili straterelli di lumachella giallo — bruna, gremita di conchiglie specialmente bivalvi (piccole ostriche, modiole, ecc.) e con non rari avanzi di echinidi; placche e radioli clavati. In certi casi il passaggio dai calcari alle lumachelle avviene in seno ad un medesimo strato, senza soluzione di continuità.

Qualche sottile intercalazione arenacea si osserva anche in questo gruppo, per es. nei dintorni di Marilè. Si tratta di un' arenaria quarzosa sottilmente stratificata, molto più compatta e cementata di quelle dei livelli inferiori, ma costituita dagli stessi minerali (non esclusa la monazite) presso a poco nelle stesse proporzioni (7.)

Il colore è bianco, ma si fa talora rosso bruno superficialmente, per alter azione. I fossili, pur troppo ordinariamente allo stato d' impronta, non vi sono rari: vi si notano impronte di una piccola *Trigonia* del gruppo della *Costatae,* ricordanti certi tipi del Lias superiore o dell' Oolitico inferiore. (*Tr. costellata* Ag., *Tr. lineolata* Ag.), piccole impronte di *Astarte,* frammenti di un *Trichites,* ecc.

Questo stesso fossile, insieme allep lacche di un echinide irregolare, forse *Clypeus* o *Pygurus*, si osservano anche in certi banchi di calcare compatto grigio - giallognolo talora brunastro o rosso vivo per alterazione, con grosse pisoliti immerse in una pasta microcristallina, detritica, con macchioline di manganese.

È questo l' ultimo strato riscontrato, e per il suo carattere oolitico fa passaggio a un tipo assai comune nella serie calcarea giurassica dell' altipiano, che costituirebbe il gruppo successivo, e che ho altra volta chiamato "serie di Bardera."

Gli strati del gruppo di Gòndar e di Marilè si ritrovano a Ferdadale, alla collinetta Caría, ai pozzi di Ircùdt (love il Sacchi raccolse una lumachella con ostriche da me pure trovatavi) e nella regione a levante di Gurràn: in tutta la zona insomma, che è compresa fra l' altipiano calcareo e le colline arenaceo - gessose di Curetca.

Lo spessore complessivo può valutarsi ad almeno 25 metri.

La Copertura.

Bisogna notare anzitutto che ora sull' uno ora altro di questi strati, indifferentemente, riposano non di rado tufi liparitici (8) e basalti (9).

Al M. Gurràn questi giacciono sui calcari più elevati di quel gruppo, ad una quota di circa 340 m. s. l. m.; al Curetca sulle arenarie, a quota di circa m. 200, al M. Dolo Godùt sulla dolomia, a m. 105, all' Agghertàr direttamente sul gesso, a circa 100 m.; ma al M. Afmedòu, intermedio fra questi ultimi due, il basalto su calcari marnosi, a quasi 250 m. s. l. m. Questa giacitura, altimetricamente e stratigraficamente così varia, anche

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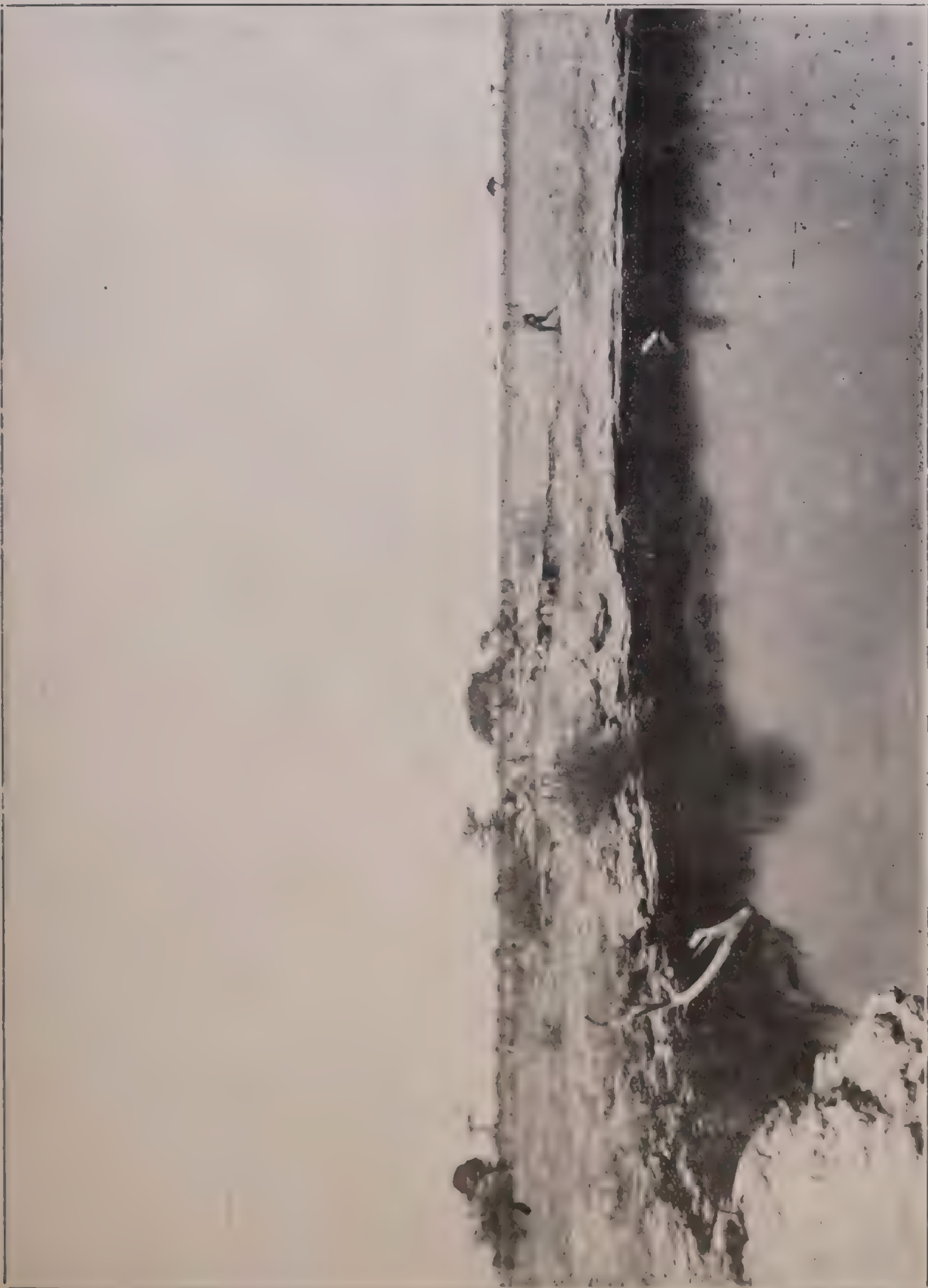

Fig. 6. Gessi del gruppo di Dolo Godùt allo stagno di Ogarca.

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Fig. 7. Marne a calcari marnosi del gruppo di Dolo Godùt.

in località vicine, e il fatto che rocce eruttive analoghe si riscontrino più a sud sui calcari del Giurassico, altrove perfino forse su terreni mesocretacei, allontanano senz' altro il sospetto che possa trattarsi di rocce eruttive antiche, paragonabili in qualche modo alle lave di Drachensberg nel Sud Africa. Le rocce eruttive della Somalia sono del tutto indipendenti dai terreni sedimentari su cui riposano: non hanno (per quanto mi fu dato osservare) intercalazioni di strati sedimentari, se non piroclastici e debbono essere state emesse nel Terziario, quando il paese era già stato modellato durante un lunghissimo periodo di tempo dalle azioni subaeree, ma prima che il Giuba si scavasse nei calcari le sue gole di erosione.

Sebbene una diretta sovrapposizione non sia visibile, almeno nelle regioni finora percorse, è da ritenere che la copertura della serie di Lugh sia invece rappresentata da quella serie, nettamente calcarea e francamente marina, che costituisce gli altipiani di Bardera — donde il nome da me proposto di serie di Bardera — e che di qui si estenda alla regione di Allengo (tra Bardera e Lugh), al Baidoa, alla regione di Uegìt e di Uddùr e più oltre verso nord.

Questa ipotesi, in mancanza di dati stratigrafici, è fondata sia su analogie litologiche, costituite principalmente dalla presenza, nei termini più elevati della "serie di Lugh," di calcari oolitici e di lumachelle, che si ritrovano in gran copia nella "serie di Bardera"; sia sui pochi dati paleontologici che accennano già nel gruppo di Gòndar ad un' età oolitica: sia anche sui rapporti topografici ed altimetrici di giacitura, i quali in regioni a stratigrafia indisturbata e a morfologia tabulare possono entro certi limiti far le veci di una sovrapposizione visibile. Ora, procedendo da Lugh (m. 165) verso levante noi riscontriamo precisamente la regolare successione degli strati dal più antico al più recente, finchè si giunge ai calcari compatti degli altipiani di Uegit (m. 406) e di Uddùr (m. 523) di età sicuramente giurassica: e identica successione osserviamo procedendo sempre da Lugh (m. 165) verso sud, fino a raggiungere l' altipiano calcareo del Baidoa a Berdale (479 m.).

Non è anzi da escludere, che i termini più bassi di quella che fu da me (10) descritta come "serie di Bardera" corrispondano cronologicamente ai termini più elevati della "serie di Lugh" e ne rappresentino solo depositi eteropici; ma questo problema coinvolge questioni, che sarebbe prematuro e inopportuno trattare ora. Meglio limitarci qui a considerare in sè stessa la "serie di Lugh."

Caratteri Generali Della Serie di Lugh.

Recapitolando, nella "serie di Lugh" noi abbiamo una successione di strati dello spessore di circa 130 m.: rappresentanti sedimenti di carattere strettamente litoraneo, anzi per la maggior parte lagunare, legati

indissolubilmente tra loro da un sistema d' intercalazioni così intimo, che riesce arduo introdurvi dei raggruppamenti, onde le distinzioni proposte in singoli gruppi sono da considerarsi come alquanto artificiali e provvisorie.

In un primo tempo (*gruppo arenaceo - gessoso - salifero di Hele Scid*) il carattere lagunare si accentua gradatamente, e dai primi strati, forse lacustri, (arenarie grigio — verdastre con *Colobodus*) si passa ad arenarie variegate e gessifere, a marne arenacee con sale, ai primi banchi di gesso. Non ostante qualche sottile e varia intercalazione di depositi indicanti una salsedine presso a poco normale (lumachella a *Mytilus* cfr. *psilonoti*) questo carattere lagunare raggiunge il suo acme nel *gruppo gessoso — arenaceo di Dolo Godùt,* in cui i banchi di gesso sono più volte ripetuti con grosso spessore e grande estensione. Più in alto le assise marnose e calcaree si fanno via via di gran lunga prevalenti su le arenarie, solo eccezionalmente gessifere verso la base (gruppo marnoso — arenaceo di Gurràn); e si assiste al passaggio graduale, per alternanze, verso il regime normale, esclusivamente marino.

Questo si realizza soltanto col *gruppo marnoso - calcareo - arenaceo* di Gòndar, che della sua facies litorale ed epicontinentale conserva tuttavia le tracce nelle lenticelle caratteristiche dei suoi calcari, nell' abbondanza delle lumachelle, in qualche alternanza di arenarie, contenenti però resti di organisimi stenoalini, come gli echinidi e i brachiopodi.

Con questo momento, o con quello immediatamente precedente, si deve ragionevolmente far coincidere quell' avanzata del mare verso sud, che depositò sui graniti di Egherta e di Matagoi i primi strati di lumachelle a *Megalodon, Perna, Trichites,* ecc., che, preceduti da un esile straterello basale di arenaria quarzoso — feldspatica grossolana, a cemento calcareo, o di calcare a grani di quarzo, rappresentno l'imbasamento della "serie di Bardera."

Le innumerevoli alternanze e ripetizioni stratigrafiche della serie di Lugh, potranno lasciar supporre, (come in ogni serie strettamente litoranea e lagunare) brevi periodi di emersione; è però escluso che essa sia incompleta e lacunosa; e nei riguardi dell' età, se teniamo presenti quegli indissolubuli legami di cui si è fatto cenno e il progressivo variare delle facies, noi potremo considerarla come continua.

Probabile eta Della Serie di Lugh.

Da quanto sopra si è esposto resulta dunque che la "serie di Lugh" è costituita da depositi in parte lagunari in parte strettamente litorali, formatisi senza gravi interruzioni o lacune. Questi strati sono, sebbene poveramente, fossiliferi alla base e alla sommità.

I fossili degli strati basali (*Colobodus, Hybodus*) accennano ad un periodo corrispondente al Trias medio o superiore o al Retico; più probabil-

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Fig. 8. Collina di Gurrán. Strati a *Eugnathus* sp

mente però al Retico che al Trias, poichè il gen. *Colobodus* è frequente tanto nel Retico quanto nel Trias superiore, nel Ladinico, nella Lettenkohle, nel Muschelkalk; e il modesto spessore di sedimenti, che separa in Somalia gli strati con *Colobodus* da quello con *Mytilus* cfr. *psilonoti*, senza che alcuna discontinuità di facies permetta di supporre l'esistenza di una lacuna, induce a ritenere si tratti di sedimenti relativamente giovani. La marna indurita passante a lumachella di microgasteropodi, con *Mytilus* cfr. *psilonoti* Quenst. (11), alla base del gruppo di Dolo Godùt dovrebbe infatti corrispondere, come nei giacimenti classici, al primissimo livello del Lias

Il Lias verrebbe così ad essere rappresentato in Somalia da un complesso dello spessore di un'ottantina di metri, di sedimenti arenaceo-gessosi alla base (gruppo di Dolo Godùt) e marnoso-arenacei (gruppo di Gurràn) al sommo, dove contiene *Eugnatus* e fa passaggio all'Oolitico inferiore.

Non vi è infatti dubbio per me, che il gruppo calcareo-marnoso di Gòndar, con le sue *Trigonia* del tipo *costatae* e le sue piccole ostriche, coi suoi Clypeidi e le sue *Astarte*, rappresenti già il primo orizzonte dell' Oolitico, equivalente dunque dei termini bassi della "serie di Bardera."

Non mi dissimulo che la proposta di abbandonare in parte la vecchia interpretazione, che considerava in blocco la formazione gessoso-arenacea di Lugh (del resto allora solo parzialmente ed imperfettamente nota) come equivalente al Trias Germanico, di cui presenta in modo così suggestivo la facies, potrà sembrare a tutta prima sconcertante. Tuttavia io non posso fare a meno di osservare, che non mancano alcune analogie anche di carattere litologico: per esempio con la serie liasica del Portogallo Settentrionale, (12) dove l'Hettangiano è rappresentato alla base da arenarie gessifere e da dolomia, che si estende anche al Sinemuriano.

Assai più significativo è il caso che si verifica nel Nord di Madagascar. Quivi il Lemoine (13) ascrive appunto al Lias una formazone di argille e arenarie bianche e versicolori, affini come facies al Trias germanico e agli strati del Karroo, ma sormontate senza discontinuità da argille con ammoniti del Lias superiore. La successione stabilita a Madagascar (anche se il Krenkel (14) tende ora ad ammetfere che questa serie abbracci pure il Trias) è di grande conforto alla mia tesi.

Ciò che si osserva nel Kenyaland, e specialmente nel retroterra di Mombasa, sembra parimente accordarsi assai bene con queste vedute. Com'è noto, nel retroterra di Mombasa sono largamente estese formazioni prevalentemente arenacee o arenaceo-marnose, che sebbene prive d'intercalazioni gessose e in parte sicuramente più antiche delle nostre, non mancano tuttavia di affinità litologiche e stratigrafiche con queste. Sono le così dette "Duruma Sandstones": un complesso di notevole spessore, che gli autori scindono in cinque membri: i "Taru Grits" del Permiano, i "Samburu Grits," i Maji-ja-Chumwi Beds (con *Estheria, Thuyites e Carpolites*) e le "Mariakani Sandstones" ascritti al Trias e finalmente le "Mazeras" e le "Shimba Sandstones."

Questi strati di Mazeras si presentano come arenarie grossolane con tronchi silicizzati, prostrati, pertinenti al gen. *Cedroxylon;* arenarie tenere bianche, con grani di quarzo e feldspato e cemento muscovitico, alternanti con marne verdi e zonate di rosso, bianche, grigie ecc. e sono ricoperte dalla "serie calcareo-marnosa di Changgamwe" contenente fossili marini di età batoniana (calcari di Kambe) e Oxfordiano-Sequaniana.

Il Gregory (15), a dire il vero, mentre ritiene che queste arenarie di Mazeras siano più recenti degli strati di Tanga, attribuiti al Trias, si mostrerebbe esitante ad accettare per esse un'età corrispondente al Retico; e, ponendo in rilievo presunti rapporti di discordanza fra i calcari del Dogger e le sottoposte arenarie, finisce coll'attribuire ai termini più elevati della serie di Duruma un'età triassica superiore. Esisterebbe insomma una lacuna, corrispondente all'Infralias e al Lias.

Va però notato che il Muff (16), al quale si deve uno studio molto accurato della regione, nel descrivere le formazioni geologiche dell'estuarie del Mwachi, avverte come quivi si osservi, interstratificato in alto alle arenarie, un grosso banco calcareo con zone oolitiche e pisolitiche, mentre a breve distanza dai primi strati della serie di Changamwe, alle marne s'intercala uno strato di calcare grigio compatto, duro, con granelli di quarzo e di feldspato, ricco di foraminiferi e frammenti di echinodermi, brachiopodi e molluschi, tra i quali riconobbe il gen. *Ostrea.* Ora tutto questo farebbe pensare, piuttosto che ad una lacuna (come ammeterebbe il Gregory), ad un graduale passaggio, per intercalazioni, dalla facies continentale attraverso una fase litorale, alla facies marina che caratterizza l'Oolitico.

E il Krenkel (17) infatti, descrivendo questa stessa successione stratigrafica, fa rilevare come le arenarie e gli scisti argillosi rossastri e violetti della base della serie di Changamwe costituiscano un passaggio da questa alla sottoposta serie di Mazeras; passaggio la cui continuità sarebbe confermata da rapporti di concordanza stratigrafica.

In tal caso le arenarie di Mazeras dovrebbero colmare interamente la lacuna fra il Trias e il Batoniano, abbracciando non solo il Retico, ma anche (sebbene per ora almeno non separabile) il Lias (18) e forse anche parte dell'Oolitico più antico. Si avrebbe insomma, in questa regione relativamente assai prossima alla Somalia, qualcosa di molto analogo a quanto si verifica nella colonia italiana, con la differenza che a Lugh la serie ha carattere lagunare, rivelato dalle abbondanti sedimentazioni di gesso e sale intercalate alle arenarie, mentre le arenarie di Mazeras con tronchi di *Cedroxylon* sono da ritenersi più francamente continentali; ma all'aridità del clima, di cui i gessi di Lugh sono un indizio, accenna dal canto suo il Krenkel, rilevando il carattere desertico degli scisti argillosi rossicci e violetti di Mombasa.

In conclusione la "serie di Lugh" abbraccerebbe un periodo, che nella classificazione europea va presso a poco dal Trias superiore o dal Retico al

Bajociano o al Batoniano, e trova una corrispondenza spiccata con serie analoghe di Madagascar e del Kenyaland.

Se si voglia ora addivenire ad un più stretto confronto di questa con altre formazioni, di regioni africane diverse, il primo punto da considerare è quello che si riferisce alle formazioni con resti di *Colobodus*.

L'importanza particolare del ritrovamento di questo fossile in Somalia sta nel fatto, già sopra accennato, che *Colobodus* comparisce in diversi altri giacimenti africani. Ricorderemo anzitutto gli strati di Lualaba nel Congo Belga (19), che il Fourmarier (20) attribuisce appunto al Trias superiore o al Retico; le marne grigio-scure di Makeya e i calcari oolitici di Mpata nel Nyasaland, ascritti da Andrew e Bailey ai livelli superiori della serie di Karroo, e finalmente gli scisti con carbone di Kidodi nel Tanganyika, ove *Colobodus africanus* fu segnalato da Wade (22).

In tanta miseria di dati paleontologici questa larga diffusione di *Colobodus* non può non esser presa a base di una sincronizzazione: sebbene non si possa naturalmente escludere in modo assoluto l'ipotesi contraria, dovremo di necessità partire dal concetto, che tutte queste formazioni con *Colobodus* siano all'ingrosso della stessa età.

Vediamo del resto, che i parallelismi così stabiliti non sono in contrasto con le deduzioni precedenti: essi accennano da un lato al Trias superiore o al Retico, dall'altro ai livelli più elevati della serie del Karroo.

In questa il gen. *Colobodus* non fu ancora segnalato; ma un livello con ittiofauna assai abbondante (tra la quale contano forme di Semionotidi associate nel Congo a *Colobodus*) fu segnalato nel gruppo superiore o "serie di Stormberg." Questa sola, del resto, può — per molti motivi — essere presa qui in considerazione: le altre (Ecca, Beaufort) sono indiscutibilmente più antiche.

La "serie di Stormberg" coi suoi tre membri (Molteno Sandstone, Red Beds e Cave Sandstone) era fino a poco fa ritenuta unanimemente comprensiva del periodo Retico-Giurassico inferiore, e in tal caso il parellelismo con gli strati di Lugh sarebbe stato (a parte la facies gessifera di questi) quasi perfetta. Recentemente però si è fatta strada tra i geologi (23) la tendenza a invecchiare notevolmente questi strati, considerendoli come triassici alla base, e non più recenti del Retico nel loro membro superiore, la "Cave Sandstone."

Per dire il vero la "crescente aridità del clima" che si manifesta durante la deposizione degli strati di Stormberg e che (considerata come caratteristica del Trias) fu invocata da Haughton nel suo bel lavoro di sintesi (24) come uno degli argomenti in favore di questa attribuzione, ha ben poco peso, dopo quanto si è visto accadere in Somalia, al Madagascar, a Mombasa, dove dappertutto i depositi liassici o presunti tali presentano precisamente una facies spiccatamente arida, talora desertica addirittura.

Ma io non sono in grado di discutere gli altri argomenti addotti dagli autori, circa la fauna erpetologica degli strati di Stormberg: debbo quindi rimettermi alle loro conclusioni. Noterò soltanto che lo HAUGHTON è a questo proposito molto prudente: egli si limita a dire che " in mancanza di argomenti a favore della teoria dell'età giurassica di parte della serie . . . . conviene concludere che questa . . . . cominciò nel Triassico medio e terminò nel Retico.

Accettando simile conclusione, la "serie di Lugh" potrebbe parallelizzarsi solo in parte a quella del Karroo, e precisamente il livello più basso della prima (quello che ho chiamato gruppo di Hele Scid) si porrebbe al livello della " Cave Sandstone." E se si vuole, non mancheremo di rintracciare qualche analogia litologica fra le arenarie sottili giallo-chiare con legni silicizzati e intercalazioni basali ricche di avanzi di pesci e crostacei, del la Cave Sandstone, e le arenarie di Hele Scid; però analogie maggiori sotto questo aspetto si riscontrano con gli "strati rossi" variegati e marnosi, e con le arenarie lasse, feldspatiche, ricristallizzate di Molteno.

Ma queste analogie litologiche hanno in sostanza scarso peso, in confronto dei ,pur poveri, dati paleontologico-stratigrafici; e questi, se si accettino le vedute degli autori recenti circa la serie del Karroo, e le mie conclusioni circa quella di Lugh, indicherebbero, come già si è detto, un parallelismo tra il livello più elevato di quella (Cave Sandstone) e il più basso di questa (gruppo di Hele Scid.)

Gli altri gruppi della "serie di Lugh" sono più recenti: essi colmerebbero — in modo del resto assai interessante — la lacuna compresa tra la fine del Retico e la fase talassocratica giurassica.

(1) G. DE ANGELIS D' OSSAT e F. MILLOSEVICH. Studio geologico sul materiale raccolto da M. Sacchi (Seconda Spedizione Bottego). Roma, 1900.

(2) MISSIONE STEFANINI — PAOLI. Ricerche idrogeologiche, botaniche ed entomologiche nella Somalia Italiana Meridionale 1913. Firenze, 1916. — STEFANINI G. Sur la constitution géologique de la Somalie Italienne Meridionale. C. R. XII Sess. Congr. Géol. Intern. 2 fasc. Liege, 1925, pag. 1059-1072, pl. XVII-XVIII.

(3) STEFANINI G. Primi risultati geologici della Missione della R. Soc. Geogr. in Somalia (1924.) Rend. R. Acc. Lincei (6) I, 1 sem. fasc. 4 Roma, 1925, pag. 182-188 cart.

(4) ARTINI E. Intorno alla composizione mineralogica di alcune sabbie ed arenarie raccolte dalla Missione Scientifica Stefanini — Paoli nella Somalia Italiana. Atti Soc. Ital. Sc. Nat. LIV. Pavia, 1915, pag. 139-168, tav. IV. Cfr. pure: ARTINI E. Sabbie e arenarie della Somalia Italiana in: Missione Stefanini — Paoli L. cit., pag. 191-195.

(5) ARTINI, E. Sulla presenza della monazite nelle sabbie e nella arenarie della Somalia Meridionale. Rend. A. Acc. Lincei (5) XXIV, 1 sem., fasc. 6. Roma, 1915, pag. 555-558.

(6) Cfr. ARTINI. Intorno alla compos. mineralogica ecc.
(7) Cfr. ATINI. Ibidem.
(8) MANASSE, E. Rocce della Somalia Italiana raccolte dalla Missione Scientifica Stefanini—Paoli (1913). Atti Soc. Tosc. Sc. Nat. Mem. XXXI, Pisa, 1916, 74 pagg. 3 tavv.
(9) ALOISI, P. Rocce della Somalia Italiana raccolte dalla seconda Missione Stefanini. Atti Soc. Tosc. Sc. Nat. Mem. XXXVIII. Pisa, 1927, 23 pagg. Cfr. pure: MANASSE, Loc. cit.
(10) STEFANINI, G. Sur la constitution etc. Loc. cit.
(11) L'esemplare della collezione Sacchi, che io potei esaminare nel Museo Geologico di Roma, grazie alla cortesia di quella Direzione, e in particolare dell'Aiuto, prof. S. Cerulli Irelli, è assai ben riprodotto nelle figure del De Angelis (L. cit.—tav. III, fig. 3); ma appunto per questo è sicuramente un *Mytilus* e non una *Modiola*, l'umbone essendo nettamente terminale, acuto, e la forma non alata, quasi simmetrica. Mi par e si avvicini molto al *M. psilonoti* Quenstedt (Der Jura, tav. 48, pag. 10), che del resto appartiene allo stesso primo livello del Lias, ma che sarebbe citato (come rilevò lo stesso De Angelis) anche dal Trias a facies gessosa dell'Algeria. L'esemplare della Somalia è di statura alquanto minore del tipo; ma ciò può dipendere dalle sfavorevoli condizioni di ambiente in cui visse.
(12) Cfr. CHOFFAT cit. in HAUG, E., Traité de Géologie II, 2.
(13) LEMOINE, P. Étude géologique dans le Nord de Madagascar. Paris, Hermann, 1906.
(14) KRENKEL, E. Geol. Afrikas I th. Berlin, 1925, pag. 354.
(15) GREGORY, J. W. The Age of the Duruma Sandstone, East Africa, Geol. Mag. LXIII, n. 740 London, 1926, pag. 83-85.
(16) MUFF BRANTWOOD, H. Report relating to the Geology of the East Africa Protectorate. Colon. Rep. Miscell. n. 45 London, 1908.
(17) KRENKEL, E. Geologische Beobachtungen in Britisch Ostafrika. N. Jahrb. für Min. Geol. Pal. Bl. Bd. XXXI, Stuttgart 1911, pag. 243-267. Anche nell' Africa Orientale gia Tedesca, lungo la ferrovia Dar-es-Salaam—Tanganica, HENNIG ha dimostrato, del resto, che la facies del Karroo si continua quivi fino ai limiti del Dogger.
(18) Cfr. KRENKEL, Ibid., pag. 255.
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Fig. 1. La pianura del Giuba presso Lugh e le colline testimoni.
Fig. 2. Le arenarie variegate con *Colodobus* cfr. *maximus* di Hele Scid (Lugh).
Fig. 3. Marne arenacee fogliettate versicolori con gesso e sale di Hele Scid (Lugh).
Fig. 4. Saline naturali di. Aggherràr presso Lugh.
Fig. 5. Collina di Dolo Godut (gessi e arenarie) e profilo dei Monti Curetca.
Fif. 6. Gessi del gruppo di Dolo Godùt allo stagno di Ogarca.
Fig. 7. Marne a calcari marnosi del gruppo di Dolo Godùt.
Fig. 8. Collina di Gurràn. Strati a *Eugnathus* sp.

ABSTRACT.

On the Sequence and Age of the Lugh Standstones, Italian Somaliland.

The formation of the Lugh gypseous sandstones, till now incompletely known, is described here on the basis of recent explorations and correlated to other better known formations.

The Lugh sandstones are ca. 130 m. thick, and their sequence is as follows, from the bottom to the top: I) multicoloured fine-grained sandstones with teeth and scales of *Colobodus* sp., and *Hybodus* sp., passing into foliated marls with gypsum and rock salt bearing layers; 2) thick beds of gypsum with interbedded multicoloured sandstones and arenaceous marls and thin bands of hardened yellow marls sometimes full of fragmentary remains of microgastropods and shells of *Mytilus* cfr. *psilonoti;* 3) marls, grits and sandstones with *Eugnathus* sp., alternating with argillaceous limestones and beds of dolomite with chalcedony geodes; 4) compact limestones with thin lenticular bands and yellow limestones full of fragmentary fossils (*Exogyra* sp.), argillaceous standstones with some beds of white hard grits weathering in purplish black (*Trigonia aff. costata, Trichites* sp., *Astarte* sp. etc.) suceeded by yellowish or red pisolitic limestone.

This series, whose underground is unknown, lies practically horizontal and is generally thin-bedded and locally covered by liparitic tufa and basaltic lavas, independent from the underground and probably tertiary in age. It passes probably into pisolitic limestones, frequently full of fossils, and grey shales with a rich fauna of the Lower Oolitic, exposed on the banks of Juba river near Bardera. It forms a lithologically indivisible whole; but the gradual change of lithological characters set in, marks the passage from a lacustrine condition through a lagoon phase to a purely marine condition.

In spite of their lithological facies, very similar to that of the "german" Trias (Keuper), it seems possible that the *Colobodus* sandstone at the basis corresponds to the Raethic stage; in this case the whole series could be attributed to the Infralias and Lias, rising with its last terms as high as Lower Oolite.

It is noticeable that in the Belgian Congo *Colobodus* is present in the strata of Lualaba, equally attributed by Fourmarier to the Upper Trias or to the Raethic; in the North of Madagascar Lias is also represented by multicoloured sandstones and marls (Lemoine). As to the Duruma series (British East Africa), it seems that the strata of Lugh can be correlated to the uppermost members of it (Mazeras and Shimba sandstones), near the top of which are also interbedded pisolitic or compact limestones, with marine stenohaline fossils (Muff).

Accepting these correlations, the Lugh standstones would be, as regards at least their lowest beds, on the same horizon as the Stormberg series in the Karroo formation.

27. A SHORT REVIEW OF THE KARROO FOSSIL FLORA

BY

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Introduction. For several reasons this subject presents some very difficult problems. First of all the Karroo System, despite its enormously wide distribution, great thickness and continental origin, is on the whole surprisingly poor in plant remains; secondly, very little systematic collecting has been done upon it, even from bands or zones that are known to be fossiliferous and that incidentally have supplied the bulk of the described material, and, thirdly, the number of genera and species hitherto recorded is lamentably few.

The rather meagre floral lists available [1]) have furthermore to be interpreted with caution. In certain areas, during certain geological periods, geographical or ecological conditions were unfavourable for vegetable life or for its preservation in the "basin deposits" of the Karroo System, and for such reasons the plants, accidentally and scantily entombed in the sediments, can hardly be regarded as fully representative of the vegetation of the vast extent of the continent at those times. The natural tendency would be to lay undue stress upon the composition of the more varied assemblages preserved within the several deltaic phases of the System, for example in the Ecca Coal Measures and Molteno Beds of the Union, and the Wankie and Somabula Beds of Southern Rhodesia, which actually constitute only a relatively small proportion of the entire Succession. Again, considering the full stratigraphical column, there are considerable sections thereof from which scarcely a plant fragment has been gathered, for example the Lower and Upper Dwyka Shales, the Lower and Upper Ecca Shales of the east, the entire Ecca of the north-west, the Red Beds and the Cave Sandstone, and an enormous amount therefore still remains to be done.

In dealing with the problems of floral migration and evolution we cannot confine our attention to South Africa as a unit, but must turn for aid to the other portions of the enormously greater Gondwanaland of which S. Africa formed merely an important part during the period extending from

[1]) For S. Africa see A. L. DU TOIT. *The Geology of S. Africa*, p. 274, 1926; for Gondwanaland, see B. SAHNI. *Proc. Thirteenth Ind. Sci. Cong.* 1926, (Tables).

the Devonian to the Liassic at least. The further aspect of these plants as indicators of their environment is too large to be more than touched upon, moreover data thereon are distinctly limited.

Where fully developed, as in the Cape Province, the Karroo sequence is an unbroken one that embraces strata ranging from the late Palaeozoic to the early Mesozoic, as shown in the following Table:—

	Series	*Stage*	*European equivalent*	
Karroo System	Stormberg	Drakensberg volcanics	Liassic	
		Cave Sandstone	Rhaetic	
		Red Beds		
		Molteno Beds	Triassic	
	Beaufort	Upper Beaufort Beds		
		Middle Beaufort Beds		
		Lower Beaufort Beds	Permian	
	Ecca	Upper Ecca Shales		
		Middle Ecca "Coal Measures"		
		Lower Ecca Shales		
	Dwyka	Upper Dwyka Shales (and White Band)	Lower	Carboniferous
		Boulder Beds (Tillite)	Upper	
		Lower Dwyka Shales.		

The Earliest Plant-bearing Strata in relation to the Glacials.

The question has been considerably obscured by the general tendency to regard the main late Palaeozoic Glaciation of the Southern Hemisphere as of "Permo-Carboniferous" or even of Permian age, an extreme view being that held by SCHUCHERT, which would actually ascribe it to the late Middle Permian. An Upper Carboniferous age is nevertheless clearly favoured, particularly by the plants, as is maintained by SEWARD, SAHNI, GOTHAN and the writer. It must be pointed out that this glaciation was, so far as can be made out, not a single episode, but consisted actually of more than one phase of refrigeration interrupted by one or more milder periods; that the centre of glaciation shifted intermittently, and that the total time involved must have been considerable.

The occurences in Argentina [2]) set the earliest phase not later than the beginning of the Upper Carboniferous, the lowest tillite being followed at one spot by beds with a Uralian fauna, and at another by beds with a

[2]) A. L. DU TOIT. *Carnegie Institution*, Publ. No. 381, p. 35, 1927.

Rhacopteris-Cardiopteris Flora, and those in turn by strata with the Gangamopteris Flora. A correspondingly early date for the glacials is also the case in the Seaham area of New South Wales, where *Cardiopteris* and *Rhacopteris* occur, and in the Kimberley district of Western Australia. There are no reasons why the Dwyka tillite should not be equally ancient, for it is, so far as can be made out, conformable in the Southern Karroo through the medium of the Lower Dwyka Shales with the Witteberg Series, which contains an Upper Devonian-Lower Carboniferous Flora, and it has furthermore a maximum thickness much greater than that of any of the Pleistocene boulder-clays.

Geological evidence is by no means opposed to the view, advanced in this paper, that the Dwyka glaciation commenced so far back as during the Lower Carboniferous, that it ended before the close of the Upper Carboniferous, although ice-sheets persisted well into the Permian in certain other parts of Gondwanaland, e.g. in New South Wales and probably in Bolivia. It is of no small significance, that throughout the Southern Hemisphere hardly ever do any post-Lower Carboniferous strata contain an indisputable Upper Carboniferous fauna or flora of "Northern" facies; instead we find the so-called "Permo-Carboniferous" deposits of Gondwana type. Towards or at their base are glacials, which over wide areas rest with unconformity upon older rocks, the youngest of which can be referred indisputably to the Lower Carboniferous, while higher up are found horizons carrying fossils with unquestionable Lower Permian affinities. In the absence of palaeontological evidence to the contrary, it is but logical to conclude that the basal parts at least of these Gondwana formations must be the local equivalents of some part, if not the whole, of the Upper Carboniferous, a view which obtains full support from those few cases, where fossils of undoubted Northern types have been discovered in them, as in Argentina or Western Australia. Elsewhere their exact position in the geological column remains more or less indeterminate, since the associated fauna or flora is almost wholly a "Southern" one.

We are therefore driven to conclude that the great cycle of late Palaeozoic refrigeration began during about the end of the Lower Carboniferous Epoch. This was attended incidentally by striking biological changes that involved the wiping out of most of the plant life and by the rise of the Gangamopteris-Glossopteris Flora.

Now it is usually overlooked that almost as notable a floristic change took place in the Northern Hemisphere at precisely the same date, the synchronism of which with the revolution in the southern half of the globe can scarcely be dismissed as one of mere coincidence. We can not therefore avoid connecting the break in floral evolution in the north with the parallel, though otherwise very different, change in the plant life within Gondwanaland, which latter was undoubtedly due to the onset of refrigeration in the south.

In the former region there came about the extinction of numerous species, the evolution of new forms, and, as pointed out by KIDSTON, an actual simplification of certain plant structures. This break in the north between the Upper Devonian-Lower Carboniferous and the Upper Carboniferous-Lower Permian Floras[3]) has always appeared mysterious, but under this view receives simple explanation, as arising primarily out of the correlated climatic changes that were induced through the intense refrigeration in the south, a subject into which it is impossible to enter here. The various instances of glacial conditions during the Upper Carboniferous reported from North America and Europe are indeed not without significance. In Gondwanaland the cosmopolitan Lower Carboniferous Flora became extinguished over much of that territory, and was replaced by the less diverse, distinct and apparently unrelated Gangamopteris Flora. In the west of that continent, in Argentina, Brazil and S. Africa certain northern Carboniferous plants nevertheless flourished, which are generally regarded as having penetrated from the north into Gondwanaland, as the climate over the latter gradually became less rigorous. SAHNI [4]) has on the contrary pointed out that they could equally well, and indeed more naturally, be viewed as descendants from the actual Lower Carboniferous stocks that are known to have existed in those several areas, rather than as invaders.

While this view is the more logical one, the available evidence is not wholly favourable thereto. First, these northern elements are hardly represented in the "Permo-Carboniferous" of Australia or India despite the presence in those countries during the Lower Carboniferous of a typical northern flora; secondly, as D. WHITE's researches have shown, they make their appearance in the Bonito Beds of Brazil only *after* the Gangamopteris Flora had already been established there; and thirdly, they are found at a distinctly later date still in the Ecca Coal Measures of Vereeniging. It is nevertheless true that, although there are serious differences of opinion regarding the generic position of most of the plants from the Witteberg Series and also of certain from the Lower Karroo Beds, at least a couple of forms are known from those respective formations that are practically indistinguishable, while further collecting may possibly provide further links.

The intimate association of the two contrasted floras in Argentina, taken in conjunction with the above observations, rather suggests that those northern forms developed in Western Argentina from the indigenous Carboniferous (*Rhacopteris-Cardiopteris-Lepidodendron*) Flora of that area, and spread gradually eastwards into Brazil and thence into S. Africa, and all but failed to reach India or Australia.[5]) How far this migration may have

[3]) Upon this and the subject generally see A. C. STEWARD's stimulating Address, "The Later Records of Plant-life," *Quart. Jour. Geol. Soc.* LXXX, 1924.

[4]) B. SAHNI. Proc. *Thirteenth Indian Sci. Congr.*, p. 243, 1926.

[5]) *Lepidodendron and Sigillaria* have recently been reported from strata above the glacials near Derby, Western Australia.

been determined or controlled by climatic factors is not yet certain, though it is noteworthy that in S. Africa the movement of the several ice-centres was from west to east also (see below). In that country the land upon which these plants could have grown was situated probably to the south-west or the north-west of the Cape, the first of these alternatives being hinted at by other lines of evidence.

Source of he Gangamopteris-Glossopteris Flora.

Several remarkable generalisations become apparent if the Continental Displacement Hypothesis be accepted and the distribution of the late Palaeozoic Floras be plotted upon a map whereon the several sections of Gondwanaland have been brought more closely together, following the scheme expounded by TAYLOR and WEGENER, (see Fig. 1.) The area marked out by *Glossopteris* will then be discovered to form a huge irregular oval, inside which will lie a triangular region characterised by *Gangamopteris*, with *Rhacopteris* at the three corners thereof—in Argentina, Kashmir and New South Wales respectively. Notable is the lesser western area occupied by the shorter-lived *Gangamopteris* and the limited south-western portion

Fig. 1.—Hypothetical Continental Restoration during the Pereno—Carboniferous
sopteris; L=*Lepidodenibron;* R=*Rhacopteris.*

marked out by *Lepidodendron* and *Sigillaria.* It is furthermore striking to observe that the extension of this triangle north-eastwards leads to a widening area within which are situated the occurrences of the rather closely related "Angara Flora." Such a peculiar distribution of floras can scarcely be regarded as fortuitous.

It is most suggestive that, while *Gangamopteris* is as yet not known to have persisted in the Karroo System into the Tapinocephalus Zone of the Lower Beaufort Stage, this plant genus is found at a distinctly later date in the Zechstein of Russia, associated with reptilia indicative of the Cistecephalus Zone. Since the line of migration manifestly ran from S. Africa to Russia, probably *via* Nyasaland and India, it is just possible that *Gangamopteris* did not originate in S. Africa, but entered the latter from the S-W, W or N.-W, and hence from S. America. The problem can furthermore be attacked in another way. Nothing having yet been discovered that could represent a more primitive type of this genus, excepting perhaps *Leslya* or *Megalopteris,* we can proceed to review the several occurrences of *Gangamopteris* and note where, so far as can be judged, this form appears earliest. In all but a few cases this plant and usually with it *Glossopteris,* succeeds with a certain time-interval the main Carboniferous tillite, and is therefore "post-glacial."

In South Africa it was, however, found in 1908 by the author at Strydenburg in the Hopetown district jammed in between the tillite and a glaciated surface, and in 1921 by T. N. Leslie at Vereeniging in a thin shaly band between the morainic matter and a floor of Dolomite.[6]) It must nevertheless be recognised that in each case the overlying tillite represents not the earliest morainic material laid down, but the product of the waning ice-sheet; still before the close of glaciation *Gangamopteris* was certainly flourishing in S. Africa. Significantly, a pseudo-boulder of quartzite from the tillite at Matjesfontein in the Cape yielded a poor specimen of either a *Cordaites* or a *Psygmophyllum.* It is clear that the climate of that ancient land was not throughout of so rigorous a nature as to have inhibited plant life, or, if it had been severe, that *Gangamopteris* was sufficiently hardy to have withstood the extreme cold in certain localities. Under the latter surmise it could well have been in existence at a still earlier date, but no traces of it have as yet been found in the Lower Dwyka ("pre-glacial") shales. In San Juan, Argentina, though the evidence is not decisive, there is a strong probability of the close association of this genus with *Rhacopteris* and *Cardiopteris,* certainly with *Lepidondendron,* which suggests that *Gangamopteris* may have originated in that country. For the present S. Africa has at least an equal claim.

[6]) T. N. Leslie *Proc. Geol. Soc. S.A.* XXIV, p. XIX, 1921.

The Lower Karroo Flora.

Our knowledge concerning the vegetation of the pre-Karroo Witteberg Beds (Devono-Carboniferous), which in the south of the Karroo is conformable with the Lower Dwyka Shales, is meagre. Impressions of stems have with some doubt been referred to the genera *Lepidodendron, Cyclostigma* and *Bothrodendron*, SEWARD having grouped a number of forms under the single species *B. irregulare*. From these strata near Worcester the author has obtained fragments bearing short spirally-disposed spines, which very strongly resemble those plants from the Ecca Beds of South-West Africa described by KRAUSEL under the new generic title of *Cyclodendron* and regarded as probably gymnospermous, under which he also places those forms from the Ecca of Vereeniging named *Bothrodendron leslii* by SEWARD. The fact that a stem from the Witteberg of Prince Albert has been specifically identified with the latter is additional proof of the outward resemblance of plants from these two formations. SEWARD has furthermore identified a fragment from the Upper Dwyka Shales as *Lepidodendron australe*, a species characteristic of the Devono-Lower Carboniferous of Australia. Apart from *Gangamopteris* the only other plant remains from the Dwyka consist of some striated stems of the *Phyllotheca*-type.

There is hence a *prima facie* connection between the pre-Karroo and the Lower Karroo floras, though more collecting will be needed to establish that relationship. It is nevertheless sufficient to indicate the presence of a Carboniferous element in the Karroo flora, which as a matter of fact is quite well marked even in the Middle Ecca, beds that are usually regarded as Lower Permian. In the Ecca Series [7]) in addition to rather widely distributed forms such as *Gangamopteris cyclopteroides, Glossopteris browniana, G. angustifolia, G. indica, G. stricta and G. ampla, Vertebraria indica, Cordaites* (*Noeggerathiopsis*) *hislopi, Neuropteridium validum, Phyllotheca* and *Schizoneura*, there have also been identified *Gangamopteris kashmirensis* from Natal—described first by SEWARD from India—*Ottokaria leslii*—a genus only known elsewhere from Brazil and India—and *Cyclodendron leslii*—remove by KRAÜSEL from the genus *Bothrodendron*, which last-mentioned genus is probably represented at Newcastle, Natal. Of high importance are the forms with northern affinities, the cosmopolitan *Sigillaria brardi*, the Brazilian species *Lepidodendron pedroanum, L. vereeningense*, a species of *Psygmophyllum*—*P. kidstoni*, a species of *Cordaites*—*C.* (*Noeggerathiopsis*) *hislopi*—and fragments of *Bothrodendron, Callipteridium* and *Sphenophyllum*. *Neuropteridium* is probably a descendant from the *Cardiopteris* stock of S. America.

[7]) A. C. SEWARD. Fossil Floras of Cape Colony. *Ann. S.A. Mus.* iv. pt. i, pp. 76-101, 1903.

A. C. SEWARD & T. N. LESLIE. Permo-Carboniferous Plants from Vereniging. *Quart. Jour. Geol. Soc.* lxiv. pp. 109-125, 1908.

Up to recently but little work had been done on the silicified woods so common on various horizons in the Karroo System. Based upon material from beds in S.W. Africa, correctly taken by him as of Ecca age, KRAÜSEL[8]) has instituted four new genera *Medullopitys, Abietopitys, Phyllocladopitys* and *Taxopitys*, and also identified WALTON's genus *Phyllocladoxylon*. These five genera are of importance in possessing centripetal primary wood, a character hitherto all but unrecorded from the Southern Floras, though well known in the Northern. Spiral thickening of the tracheids, as in the living Taxoideae is to be observed in *Taxopitys* and also in *Spiroxylon*, a genus instituted by WALTON from a stem probably from the basal Beaufort Beds of Carnarvon. Two species of *Dadoxylon* from the Ecca of S.W. Africa, *D. rangei* and *D. porosum*, are considered by KRAUSEL to stand nearest to the Cordaitales.

In the succeeding Lower Beaufort Beds but little more diversity is shown by the plants. *Gangamopteris, Lepidodendron, Sigillaria*, etc., disappear and *Glossopteris* becomes the predominant genus, in the various species *browniana, indica, angustifolia, conspicua* and *retifera*, the last of which can perhaps be taken as the zone-fossil. Of moment is the finding in Natal of *G. nephroidicus* and *Sphenopteris alata* only known from N.S. Wales. *Schizoneura gondwanensis* occurring in Nyasaland also and typical of India, and *Sphenophyllum* sp. Of interest are the recent provisional determinations by WALTON from strata at Wankie, Southern Rhodesia, of *Sphenophyllum speciosm, S. thonii, Pecopteris arborescens* and *P.* cf. *arcuata*, which indicate affinities with Asia and Sumatra; the last-named genus has not hitherto been recorded from S. Africa. WALTON [9]) has pointed out the wide distribution not only in the Union and S.W. Africa, but in N.S. Wales and the Falklands of *Dadoxylon arberi*, a species that seems to be confined to the Lower Beaufort Stage; from the Stormberg Series comes a second species, *D. sclerosum.*

Considering the remarkably close resemblances shown by the Gondwana succession of S. Africa and S. America, it is peculiar that the treefern *Psaronius*, so widespread in the Permian of Brazil, has not been discovered in the Western Karroo or in S.W. Africa, but insufficient collecting is one explanation for its apparent absence.

On palaeobotanical grounds the Ecca Series can be correlated fairly closely with the Karharbari-Barakar stages of India, Greta Stage of N.S. Wales, Lower Bowen of Queensland and Bonito of Brazil—that is to say with the Lower Permian,—while the lower Beaufort would correspond with the Raniganj, Newcastle and Upper Bowen—that is to say with the Upper Permian. More or less on the border line between the Ecca and Beaufort can

[8]) R. KRÄUSEL. Fossile Pflanzenreste aus der Karruformation Deutsch-Süd-Westafrikas. *Beit. geol. Erfors. deutsch. Schutz*, Heft. 20, pp. 17-54, 1928.

[9]) J. WALTON. On South African Fossil Woods, Ann. S.A.Mus. xxii, p. 1, 1925.

be placed the plant-bearing strata of S. and N. Rhodesia, of the Lafonian of the Falklands, and of much of the Angara System of Asia, that is to say at about the top of the Lower Permian.

Mention has been made that during the Upper Permian Karroo reptilia, along with *Gangamopteris* and *Glossopteris*, reached Russia, by means of a connection between Gondwanaland and Eurasia. It was doubtless along this route that several other southern forms such as *Neuropteridium* and *Schizoneura* entered Europe and by which a few northern ones were able to travel in the opposite direction.

The Transition from the Palaeozoic to the Mesozoic.

A feature that has received insufficient attention is the remarkable impoverishment of the Glossopteris Flora during the Middle Beaufort Stage (Lowest Triassic), when plant-life—or more strictly those relics preserved in our "basin" deposits—became reduced to *Dadoxylon, Glossopteris browniana, G. angustifolia* and either *Phyllotheca* or *Schizoneura*. Such a diminution is moreover not confined to S. Africa, for the corresponding continental strata of Argentina (Paganzo), India (Panchet), and New South Wales (Narrabeen) are similarly all but unfossiliferous. Considering Gondwanaland as a whole, vegetation seems to have reached its ebb in the west and centre at this period, but such floral impoverishment is also noticeable, though by no means so marked, in both Eurasia and North America. In certain areas in the south the ecological conditions were certainly of an unfavourable kind, but that could hardly have been universal; moreover, curiously, vertebrate life seem to have remained unaffected. Brazil and S. Africa appear to have constituted the "dead heart" of Gondwanaland in the early Mesozoic and plant migration would probably have been more easily effected along the periphery of that continent; not unlikely immigration into the interior was an abnormally slow process.

In S. Africa the boundary between the Palaeozoic and the Mesozoic, based merely upon the plant-life, would undoubtedly have to be drawn at the top of the Middle Beaufort Stage, that is to say at between the Lower and Middle Triassic, appreciably later than is demanded by the standard geological table. Furthermore, as is pointed out below, there are some marked survivals of palaeozoic types even in the succeeding Upper Triassic-Rhaetic Thinnfeldia Flora not only of S. Africa (Molteno), but of other parts of Gondwanaland such as India (Parsora), Victoria (Bald Hill) and Tonkin. In dealing with India SAHNI [10]) goes even further and regards the change to the "Mesozoic" as not having been brought about until about the end of the Rhaetic Stage.

SEWARD's dictum [11]) that "connecting links between the older and newer

[10]) B. SAHNI. *Proc. Asiatic. Soc. Bengal*, xvii, p. clxiii, 1921.

[11]) A. C. SEWARD. *Quart. Jour. Geol. Soc.* lxxx, p. xc, 1924.

floras are few and mostly unconvincing" will require some qualification when applied to the Southern Hemisphere, but there undoubtedly was, as he remarks, an extraordinary botanical discontinuity in the early part of the Triassic.

Upper Karroo Flora.

Great changes took place during the later Triassic, the flora becoming not only more numerous in the uppermost Beaufort Beds, but varied, and attaining its zenith during the Upper Keuper in the Molteno Stage and in the equivalent strata of Argentina, India, Australia, Tasmania and Tonkin. The pteridosperms are largely replaced by filicales, ginkgoales and cycadophytes, while *Glossopteris* lingers on only in S. Africa and TONKIN, though it is not improbable, as suggested by SAHNI, that the plant genus *Linguifolium*, known from Chili, Tasmania and New Zealand, if not identical with *Glossopteris*, is closely allied thereto—perhaps only a derivative therefrom.

The presence in S. Africa during the Triassic of certain Central European genera of reptilia and amphibia would imply a temporary connection between Eurasia and Gondwanaland, perhaps by way of Persia, and hence it is not surprising to find appearing in the southern continent during that epoch European plant genera such as *Sagenopteris* and *Cheiropteris* and species or alliances such as *Cladophlebis nebbensis, Ginkgoites digitata, Thinnfeldia rhomboidalis, Pterophyllum* cf. *brauni*, etc. Such immigration seems indeed to have acted as a stimulus to floral evolution, for new and apparently indigenous forms now make their advent in the south.

Analysing the S. African flora, the earliest newcomer—obtained from well down in the Upper Beaufort Stage—is the large fern-like *Danaeopsis hughesi*. If this had been indigenous, fronds thereof ought to be common in the higher strata, which is not the case, so that it can be regarded as a probable invader from India, where it is abundant in the equivalent Parsora Stage. Although *Glenopteris*, from the Permian of Kansas is not improbably but a more primitive form of the polymorphic Trias-Rhaetic genus *Thinnfeldia*, the latter is typically Gondwana. It occurs well down in the Triassic both in N.S. Wales (Narrabeen) and S. Africa (Upper Beaufort), but in Europe does not make an appearance until the Rhaetic, although with the exception of *T. rhomboidalis* those northern species differ appreciably from the southern ones; indeed GOTHAN created for the Gondwana forms the genus *Dicröidium*, a distinction that has not been upheld by subsequent work. With *Thinnfeldia* can be associated the closely allied genus *Pachypteris*, which, while found in the Molteno Stage (Keuper), appears in Europe only in the liassic. The *Taeniopterids* may perhaps be descended from the Lower Gondwana species of India. *Johnstonia*, a genus of unknown affinities, has only been obtained from the Molteno Beds and from Tasmania. *Stormbergia* is a curious genus not yet discovered outside of the

Cape. The remarkable stem, *Rhexoxylon*, possibly gymnospermous found in the Cape, Natal and S. Rhodesia, is most likely African and is known elsewhere only from Antarctia, where it forms with *Glossopteris indica* proof of a connection between the latter region and Gondwanaland. *Moltenia* is a cycadophyte with a surprisingly close resemblance outwardly to the typically S. African living *Encephalartos* and is probably indigenous; it is known only from Natal and possibly from Tasmania. The cycadophyte genus *Pseudoctenis*, abundantly represented in the Molteno Stage, appears first in the Barakars (Permian) of India and may be of Gondwana origin. On the other hand that widespread plant *Ginkgoites* has not yet been discovered in Rhodesia, India or Tonkin, and, as its commonest species *G. digitata* is known from the Permian of Angaraland, this genus can perhaps be viewed as of Asiatic origin. The palmate leaves of *G. magnifolia* found in S. Africa are larger even than those described by FONTAINE and WARD from Virginia. *Chiropteris* and *Lepidopteris*, the latter known from Madagascar as well as from the Cape, are typically European Triassic genera, while *Callipteridium* finds its nearest allies in European Permian forms. *Voltzia* and the *Pterophyllums* from the Karroo are of Eurasian species and alliances.

The author [12]) has pointed out that the Upper Karroo Floras, while predominantly Mesozoic in their aspect, contain a Permian element composed of pteridosperms and plants of doubtful systematic position, partly European, partly belonging to the Glossopteris Flora, for example, *Callipteridium*, *Odontopteris*, *Sphenopteris*, *Glossopteris*, *Voltzia*, and *Stigmatodendron*. The same survival of late Palaeozoic types is marked in the equivalent floras of India, Tonkin and to a less extent of Victoria, Queensland and Tasmania. The alliances are otherwise with Triassic and Rhaetic forms, not only of Gondwanaland, but of Persia, Germany, Sweden and even Virginia. That assemblage contained in the Upper Beaufort Stage is regarded as not younger than Lower or Middle Keuper, and that of the succeeding Molteno Stage as of Upper Keuper age.

Placing together these two closely associated assemblages and analysing them, we can with a certain amount of probability regard as indigenous to S. Africa *Stormbergia*, *Moltenia* and *Rhexoxylon*; as Gondwana—though probably extra-African—*Thinnfeldia*, *Pachypteris*, *Danaeopsis*, *Stenopteris*, *Johnstonia*, *Pseudoctenis* and *Glossopteris*; as Eurasian *Chiropteris*, *Sphenopteris*, *Ginkgoites*, *Baiera*, *Pterophyllum*, *Voltzia* and perhaps *Nilssonia*.

It unfortunately happens that the succeeding Red Beds and Cave Sandstone (Rhaetic) have only yielded some isolated specimens ascribed to *Pachypteris*, *Schizoneura* and *Dadoxylon*, so that the alliances of the plants from the highest Karroo strata cannot in fairness be discussed, though from similar zones in East Africa near Tanga in SEWARD has described *Voltzia*, *Ullmannia* and *Eresmophyllum* (?) The Jurassic has not been identified in

[12]) A. L. DU TOIT. *Ann. S.A.Mus.* xxii, p. 310, 1928.

S. Africa, and a serious gap intervenes between the Karroo System and the Uitenhage Series, which carries a Wealden Flora. It might be noted, however, that a few species characterising the Molteno Stage, and also some allied forms, occur in the Rajmahal Flora of India,[13]) which is Jurassic in age. As pointed out by SEWARD, there was a wonderful uniformity in the vegetation of the world during the Rhaetic and Liassic, the explanation of which is not altogether clear.

Ecological Considerations.

It is commonly assumed that the "Northern" Carboniferous Flora became extinct in the south through inability to withstand the intensity of the late Palaeozoic refrigeration, but such a view may not be altogether correct. In San Juan, Argentina,[14]) shales not many feet above the Carboniferous ground-moraine carry *Rhacopteris, Cardiopteris,* etc., and are followed by sandstones and by a second and a third tillite. While admitting that those sediments can be regarded as interglacial deposits, it is clear that typical northern plants were able to maintain an existence in the neighbourhood of an oscillating ice-front. This argument applies as well to the occurrence of *Gangamopteris* in intimate association with the tillite of S. Africa and also of Victoria, and with the marine glacials of N.S. Wales.

The Lower Karroo beds may well have been, and probably were, formed under a mean temperature somewhat below normal. The coarse arkoses of the deltaic Ecca "Coal Measures" of Natal certainly suggest a cold and probably a wet climate, which the general absence of fireclays in association with the coal-seams tends to support, wherefore the presence of resistant northern forms in these strata and also in the coal-bearing Bonito Beds of Brazil and the Lower Paganzo of Argentina and their practical absence in India and Australia, may possess some meteorological significance.[15])

The lithology of the Beaufort Beds suggests on the contrary a climate becoming progressively warmer and drier, comparable conditions having seemingly prevailed at that time—during the Permo-Triassic—in S. America. Growth-rings in the *Dadoxyla* hint at alternating seasons, just as to-day. A large proportion of Gondwanaland appears to have shared in the world-wide desiccation of the Triassic, but the well known Thinnfeldia Floras therein seem to have occupied the marginal parts of that continent chiefly and occur in fluviatile intercalations that mark out interludes of lesser aridity. Under such circumstances it could hardly be expected that xerophytic characters would be in evidence in such hygrophilous vegetation. It can nevertheless be pointed out that the stomatal cells are deeply sunk

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[13]) A. L. DU TOIT. *Ann. S.A.Mus.* xxii, p. 312, 1928.

[14]) A. L. DU TOIT. *Carnegie Instu. Publ.* No. 381, pp. 28-41, 1927.

[15]) The ecological significance of the Vereeniging plants has been well dealt with by T. N. LESLIE. *Proc. Geol. Soc. S.A.* XXIV, p. XIX, 1921.

beneath, and are concealed by the guard-cells, in the cuticle of *Thinnfeldia* and of the cone-scales of *Cyparissidium*, a structure that is undoubtedly either a xerophytic or a halophytic adaptation. Furthermore a stem from the Somabula Beds of S. Rhodesia has been referred to *Pleuromeia*, a remarkable genus that is regarded by J. WALTHER as a cactus-like plant with a desert habitat, though that view has been challenged by GOTHAN.

There is little doubt that those several equivalent formations, the Cave and Bushveld Sandstones of the Union, Forest Sandstone of Rhodesia, Lubilache of the Congo, Adigrat Beds of Abyssinia, Botucatú Sandstone of Brazil, Uppermost Paganzo of Argentina and the Parsora of India, which mark the close of the Trias-Rhaetic, have in the main been accumulated under a rainfall of well below the average, some of them indeed under more or less desert conditions, and the study of the anatomy of their rather scanty plant-life can be expected to yield results of consequence.

In the Northern Hemisphere there have been great advances made in recent years towards the interpreting of past climates through the evidence of the fossil plants. In the Southern one comparatively little has been achieved, and in S. Africa, if we except LESLIE's work, not very much, so that a large and fascinating field is certainly open for palaeobotanical research. In contravention, the recognition that intense glacial conditions must have prevailed in the southern hemisphere while the Carboniferous forests were flourishing in the northern, may just possibly lead to important deductions regarding the climate of those boreal countries, upon which there are still serious differences of opinion.

28. THE ORIGIN AND AGE OF THE KARROO REPTILIA

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The stratigraphic classification of the beds of the Karroo System is well known; and the general features of the fauna and flora preserved in them have been described in a number of publications. In these notes it is proposed to discuss the various components of the fauna, mainly of the lower fossiliferous beds, to compare them with those of other parts of the earth which were contemporaneous with them, and to attempt to trace their place of origin.

The Karroo System in South Africa is subdivided as follows:—

Stormberg Series	Stormberg Volcanics	
	Cave Sandstone	
	Red Beds	
	Molteno Beds	
Beaufort Series	Upper Beaufort Beds	*Cynognathus* zone
		Procolophon zone
	Middle Beaufort Beds	*Lystrosaurus* zone.
	Lower Beaufort Beds	*Cistecephalus* zone
		Endothiodon zone
		Tapinocephalus zone
Ecca Series	Upper Ecca Beds	
	Middle Ecca Beds	
	Lower Ecca Beds	
Dwyka Series	Upper Dwyka Shales	
	Dwyka Tillite	
	Lower Dwyka Shales	

Where the succession is complete, there is complete conformity from the Lower Dwyka Shales (which are themselves conformable on the Witteberg Beds) right through to the Cave Sandstone. In a recent paper

reviewing the Late Palaeozoic Formations SCHUCHERT introduces a "great unconformity" between the Lower Dwyka Shales and the Dwyka Tillite; but this presumption is contrary to all the results obtained by work in the Southern Karroo area, where the passage from one to the other can be studied in a number of beautiful sections. There is unconformity at the base of the Tillite north of Lat. 32½° S. only, north of which latitude the Lower Dwyka Shales have not been found.

THE KARROO FAUNA (Reptiles).

The general nature of the reptilian fauna of the Karroo Beds is well-known and the inter-relationships of the various types have been discussed by a number of workers with a fairly close approach to unanimity of opinion. In most of the groups evidences of advances in structure or of specialisations with advancing time are becoming increasingly apparent: and the systematic study of the morphology of the numerous known species is enabling us to correlate certain forms with definite time-stages.

From the point of view of numbers of individuals and of species, the dominant forms of the Beaufort Beds are the Anapsid and Synapsid genera. The Diapsids play an insignificant part in the life of the greater part of Beaufort time, but become increasingly important in late Beaufort times and dominant during the Stormberg period.

Anapsida. In this sub-class the Orders Cotylosauria and Eunotosauria are represented. The former has representatives of the families *Pareiasauria* (8 species from the top of the *Endothiodon* and base of the *Cistecephalus* zones, and 1 genus and 1 species from the *Cistecephalus* zones), and *Procolophonia* (2 genera from the Upper Beaufort Beds); whilst the Eunotosauria are represented by one form only from the *Tapinocephalus* zone.

The Pareiasauria from the higher zones differ from those of the *Tapinocephalus* zone in certain features, among which may be cited the somewhat smaller size the increased number of cusps on the teeth, the occurrence of a more regular system of dermal scutes and—with the exception of *Anthodon*—the increased rugosity and more pronounced cranial bosses on the skull.

The Russian Pareiasaurs agree more closely with those of the *Cistecephalus* zone than with any others; indeed, the horn-like nature of the cranial bosses shews even more specialisation than in any known S. African genus. This specialisation seems to be carried to an extreme in the smaller allied genus *Elginia* from N. Scotland.

Procolophon, and the lesser known genus *Thelegnathus*, are confined to the Upper Beaufort Beds. They are the latest of all Cotylosauria and shew many advances and specialisations in their structure. The closest ally of *Procolophon* is *Telerpeton* from the Trias of Scotland.

Synapsida. By far the greater number both of species and individuals among the reptiles of the Beaufort Beds fall into this sub-class. This has been divided into two great Super-Orders—the Theromorpha and the Therapsida, of which the former are not represented in Africa, whilst the latter are—with very few exceptions indeed—confined to South Africa, Russia, Scotland, Brazil and India.

The lowest zone of the Beaufort Beds contains members of several Therapsid Orders—Dinocephalia, Gorgonopsia, Anomodontia, Therocephalia and Dromasauria. The Dinocephalia (including Titanosuchids and Tapinocephalids) first appear, sparingly, at the top of the Ecca Beds, attain their maximum development at and near the middle of the *Tapinocephalus* zone and become extinct before the top of that zone is reached. The Gorgonopsia of the *Tapinocephalus* zone are small, primitive and few in number; they increase in importance in the succeeding zones and extend to the top of the Lower Beaufort Beds. From the middle of the *Tapinocephalus* zone has come the specialised genus *Styracocephalus* which combines features common to the Dinocephalia and Gorgonopsia, and must be looked upon as a specialised late descendant of a common ancestor of these two Orders. The Anomodontia are represented in the lowest Beaufort Beds by two small described species of *Dicynodon* and by one or two undescribed forms of the same genus; but these beds shew nothing of the immense development of the Order that is seen in the succeeding zones of the Beaufort Series nor any of the specialisations that gave rise to such bizarre forms as *Eocyclops, Endothiodon* or *Kannemeyeria.* The Therocephalia are more fully developed in the *Tapinocephalus* zone; but the individuals are few and are of a somewhat generalised type.

Thus, except for the Dinocephalia, we may look upon the Synapsids of the *Tapinocephalus* zone as being merely the forerunners of the later and richer fauna, and as being not very far removed from an earlier type or types which contain features common to the various Therapsid Orders.

One of the earliest and most primitive Therapsids yet described from South Africa is a small skull from low down in the *Tapinocephalus* zone named *Anningia* by Broom and considered by him to be the representative of a new Order, the Anningiamorpha. The only known skull is imperfect and the features of the pre-orbital region are unknown; nevertheless, as Broom has pointed out, it shews certain affinities with some North American types such as *Mycterosaurus* and *Glaucosaurus.*

Gregory, in his discussion of the skeleton of *Moschops,* agrees with some conclusions of Broom and Watson, and argues for a common origin of the Therapsid stem and that of the Pelycosaurs. He concludes that the whole Therapsid stem was derived from unknown relatives of the Pelycosaurs. From a study of *Palaeohatteria,* Nopcsa has considered that the Pelycosauria on the one hand and the Therapsids on the other arose from a common stock; and the discovery of *Anningia* in the bottom part of the

Lower Beaufort Beds would seem to indicate that this common stock was not very far removed in point of time from the period in which those beds were deposited.

One characteristic difference between the early S. African Therapsids and the North American Pelycosaurs is in their limb-structure. The former had acquired the ability to raise the body off the ground and to walk or run rather than to crawl as did the more typically reptilian Pelycosaurs. This is generally considered to indicate an advance in structure; but it may well be a feature that was impressed upon the South African fauna as a whole by environmental conditions different from those existing for the North American fauna, and may thus not indicate any further remoteness from the ancestral stem in point of time.

It is important here to draw attention to the recent work of Nopcsa on the reptiles of the Copper-bearing Permian of Russia. Four genera are described by him:—*Deuterosaurus, Mnemeiosaurus, Rhopalodon* and *Uraniskosaurus*. The first is said to be a primitive Titanosuchid, the second a Tapinocephalid, and the other two Gorgonopsids; and Nopcsa concludes that, as three of the genera are more primitive than the reptiles of the *Tapinocephalus* zone, the beds containing them may be considered as the equivalent of the Ecca Beds. This is a conclusion of some importance, and it is necessary to examine with care the considerations upon which it is based.

Deuterosaurus is said to differ from South African Dinocephalia in features connected with the jugal, quadratojugal, quadrate and occipital region, while in all these points it approaches the more specialised Pelycosaurs. The slenderness of the postorbital, however, is paralleled in *Moschosaurus;* the shape of the jugal and its relation to the temporal fossa and squamosal are as in some Gorgonopsia and Anomodonts; the depth of the quadrate and long pedunculate articulation of the lower jaw are seen in *Moschosaurus, Delphinognathus* and other Dinocephalia; and the occipital structure is similar in all essentials to that of the less specialised Dinocephalia.

Mnemeiosaurus is in all respects a Tapinocephalid, except that pachyostosis of the skull bones has not taken place. It recalls very strongly *Delphinognathus*, but has apparently a weaker postorbital bar.

Rhopalodon is said by Nopcsa to be a true Gorgonopsian, but "a good deal more primitive than the S. African Gorgonopsidae."

On the other hand, *Uraniskosaurus* has certain features that do not seem to be primitive: the apparent absence of molars behind the large canine and the backward extension of the prevomers to meet the pterygoids in the vaulted portion of the palate are features that one would expect to find in advanced or specialised Gorgonopsia.

The conclusion is reached, therefore, that these Russian skulls are not far removed from the forms characteristic of the *Tapinocephalus* zone; and

it becomes unnecessary to suppose that the Copper-bearing Permian Beds of Russia are homotaxial with the Ecca Beds and not with the lowest beds of the Lower Beaufort, or that the Dinocephalia are "probably descendants of some rather specialised Pelycosauria" and not descendants of some common ancestor with the Pelycosauria.

It is in the *Endothiodon* and *Cistecephalus* zones that the Synapsida shew their maximum development of genera, species and individuals. Here the Dicynodonts take on a great variety of forms, separated from one another by somewhat small differences in many cases, and shewing distinct specialisations in others. The more primitive Endothiodonts, with molar teeth, are numerous and somewhat specialised. Gorgonopsia and Therocephalia attain their maximum development. The forerunners of the Cynodontia begin to appear; and the Scaloposaurids foreshadow the Bauriamorpha of the Upper Beaufort Beds. Here, too, are forms, like *Choerosaurus*, which shew features of the postcranial skeleton indicative of a great advance towards the mammalian condition.

It must be reiterated here that, with the exception of the Cynodont *Dwinia*, the Synapsids from the deposits of North Russia are clearly reminiscent of those of these two zones in South Africa. The medium-sized Dicynodonts, the large *Inostranzevia* and the Therocephalian *Anna* are all comparable with South African forms. The presence of the somewhat advanced *Dwinia* in the upper part of the deposit associated with isolated bones of "Pareiasaurus," Dicynodonts and Therocephalia is strong evidence for the presumption that the Cynodontia were an integral part of the fauna of the Lower Beaufort Beds in South Africa, a presumption supported by the presence of *Cyniscodon* in the *Tapinocephalus* zone and of *Cynosaurus* in the *Cistecephalus* zone.

Another primitive Cynodont from North Russia, not yet fully described, has been named *Permocynodon* by Sushkin. In various features, including the presence of an interpterygoid vacuity, *Permocynodon* recalls *Thrinaxodon* from the Middle Beaufort Beds; and it is interesting to note that the form comes not from the beds containing Pareiasauria in North Russia but from a higher level—the uppermost Permian.

In the Middle Beaufort Beds the Synapsida diminish considerably in the number of forms. The Gorgonopsids and Therocephalia disappear except for one or two aberrant and specialised forms which occur at the very base. The Dicynodonts are represented by numerous examples of the specialised *Lystrosaurus* and a single species of *Dicynodon*. The Cynodontia present are all small, and shew peculiarities in the postcranial skeleton, especially in the flattening and expansion of the ribs. In this zone, too, is said to occur the primitive but specialised form *Burnetia*, which—as far as is known—shews affinities with *Styracocephalus* of the *Tapinocephalus* zone, combining both Gorgonopsian and Dinocephalian features. This is, apparently, an interesting example of survival of an early type.

Repelin has described from Indo-China, under the name *Dicynodon incisivum*, a portion of an Anomodont skull. The specimen consists of a snout and palate with two tusks; from the elongation of the snout and the superior position of the nostrils it is legitimate to conclude that the specimen belongs to the genus *Lystrosaurus*, and the beds containing it should therefore be correlated with the Middle Beaufort. Repelin provisionally classes the fossil as Middle Triassic in age.

Both *Lystrosaurus* and *Dicynodon* occur in the Panchet Series (Middle Gondwana) of India, which is accepted even by SCHUCHERT as being of Upper Permian or possibly Lower Triassic in age.

The Synapsids of the Upper Beaufort Beds contain a preponderance of Cynodontia and Bauriamorpha, with a few specimens of the specialised Dicynodont *Kannemeyeria* and a survival, in the lowest beds, of *Lystrosaurus*. Cynodonts are known from North Russia; but it has already been remarked that these probably come from an earlier zone. One Cynodont has also been described from the Rio-do-Rasto Beds of Brazil and named *Gomphodontosuchus* by VON HUENE. The type skull has a gomphodont dentition; but it differs in the smaller number of molars and premolars from the Cynodonts of the Upper Beauforts and also in the possession of a small septomaxillary foramen which is plainly visible on the left side of the skull. In these features—but not in the nature of the teeth-crowns—the form is more reminiscent of the primitive Cynodonts of the *Cistecephalus* and *Lystrosaurus* zones. (VON HUENE, during his recent collecting in Brazil, has—so he informs me *in litt.*—obtained both Cynodonts and Dicynodonts; but no description of them has as yet appeared.)

The only Synapsids of the Stormberg Series are three incompletely known genera of Cynodonts from the Red Beds.

It must be noted that the following very incompletely known genera from North America have been placed by VON HUENE in the Therapsida: *Dolichobrachium*, *Eubrachiosaurus* and *Brachybrachium* from the Popo Agie Beds of Wyoming, and *Placerias* from the Shinarump Formation of Arizona. A form compared with *Placerias* is recorded by BROILI from the Upper Muschelkalk of Germany. *Dolichobrachium* is a somewhat specialised animal with certain primitive characters and may be a Theriodont. *Eubrachiosaurus* may well be a Dicynodont although it is larger than any recorded from the Karroo Beds. Of none of these forms is any skull material known, and their exact systematic position must therefore remain in doubt.

Diapsida. The Diapsids are but poorly represented in the Beaufort Beds, but such forms as do occur are of absorbing interest. Some of them are of generalised types and are regarded as ancestral forms from which many of the later Orders have sprung.

The earliest Diapsid in South Africa is *Youngina* from fairly low down in the *Cistecephalus* zone, although *Galesphyrus* from the base of the Lower

Beaufort is by both BROOM and VON HUENE considered to be closely allied to *Youngina*. The former is undoubtedly a primitive generalised representative belonging to an Order — the Eosuchia — which has hitherto been unrecognised outside Africa. In the upper part of the *Cistecephalus* zone occur *Saurosternon baini* and *Palaeagama*, which must also be placed in the Eosuchia. In a recent paper, the author has endeavoured to shew the fundamental similarly between these three forms and the genera *Tangasaurus* and *Hovasaurus* from East Africa and Madagascar, and has suggested that certain lines of descent within the Order from *Youngina* may be traced. These evolutionary lines are (1) *Youngina - Saurosternon - Palaeagama - Paliguana* leading, according to BROOM, to the Lizards; (2) *Youngina-Tangasaurus;* while *Hovasaurus* is a specialised aquatic Eosuchian. If this be accepted, then we may regard the beds containing *Tangasaurus* and *Hovasaurus* as somewhat later than the *Cistecephalus* zone and may with some certainty place them as equivalent to the Middle Beaufort Beds.

From the Lower Beaufort Beds no other Diapsids have as yet been obtained. The Middle Beauforts have yielded the skull known as *Chasmatosaurus*, which is fairly closely allied to the Upper Beaufort Pelycosimian *Erythrosuchus*. The relationships between these, the South American Pelycosimia, and the other Diapsid Orders have been fully treated by VON HUENE; his recent collecting in Brazil has shewn the presence there of the non-South African Order Parasuchia.

Proterosuchus (an early form) from the *Procolophon* zone and *Browniella* and *Euparkeria* from the *Cynognathus* zone are Upper Beaufort Pseudosuchia; whilst *Howesia* and *Mesosuchus* are Rhyncocephalia from the same zone.

ORIGIN OF THE KARROO FAUNA.

This brief review shews that at the onset of Beaufort times there were established in South Africa two great dominant groups of reptiles—the Pareiasauria and the Therapsida, the latter represented in the very beginning by several Orders—whilst the Diapsids soon begin to appear. Previous to Lower Beaufort times the only Tetrapod life is evidenced by *Mesosaurus* (whose chief place of occurrence is in Brazil) and by four-toed footprints in the Ecca of the type usually called amphibian, if one leaves out of account the very few remains from the topmost Ecca Beds.

The fossils of the lowest (*Tapinocephalus*) zone are confined to the south-western corner of the present Karroo basin; and an attempt has been made elsewhere to shew that, although the Pareiasaurs probably lived in the swamps in whose mud their skeletons were ultimately embedded, some of the Therapsids had their normal habitat on higher and drier ground. This higher ground probably lay to the south and south-west for (1) the Ecca sediments of the Cape undoubtedly were derived from the south, and (2)

had the habitat been to the north it is probable that some trace of skeletal remains would have been found in beds further north than the Gouph. (It is to be noted here that the Diapsids of Victoria West—*Heleophilus* and others—were originally thought to have represented dry-land forms of the *Tapinocephalus* zone; but the more recent ideas of Broom tend to shew that they come from the upper part of the Lower Beaufort Beds.)

Evidence can be accumulated from several localities in support of the existence of such a land-mass to the south in Dwyka times, although the Dwyka Tillite of the Cape has hitherto not been proved to contain any material that has not come from the north. (Du Toit has argued the existence of a land-mass between S. Africa and S. America from which ice radiated north-westwards into Brazil and eastwards into the Van Rhyn's Dorp area of the Cape. A land-mass in that position can also have been the collecting ground for the ice in Table Mountain Sandstone times, which has been shewn to have drifted eastwards into the southern and western Cape. It must therefore have been in existence from late Silurian to at least early Dwyka times.)

In the Falkland Isles, Baker has shewn that the Dwyka glacial beds contain boulders of rocks occurring in the Archaean series of Cape Meredith (which is to the extreme south of the West Island) and from the occurrence of striated pavements of quartzites has argued a general northward movement of the ice in that region, thus postulating the existence of a gathering ground for the ice to the south.

Southern Patagonia and the Antarctic Continent have as yet yielded no traces of Dwyka glaciation; but that they were land during Upper Palaeozoic times seems to admit of no dispute. There seems therefore nothing inherently improbable in postulating that parts of the southern land-mass were, during the Dwyka glaciation, free from ice, and able to act as a refuge—if necessary—for the ancestors of the Karroo reptilia.

Is such a refuge necessary?

The distinctness of the N. American-European (excluding Russia) Permian reptilian fauna on the one hand and the Karroo reptilia on the other is generally agreed. In the former area, undoubted reptilian remains occur in the Upper Pennsylvanian and some of them, such as *Dimetrodon* and *Edaphosaurus*, were already highly specialised Pelycosaurs. They must have had their origin further back in the Carboniferous. None of them is primitive enough to be looked upon as the ancestor of the Karroo Therapsids which must ultimately have originated from the same stem as the Pelycosaurs.

One of the most primitive reptiles known is *Seymouria*, from the Permian Beds of Clear Fork, Texas. So primitive is it that Broom believes it to be an advanced embolomerous amphibian and Sushkin also believed it to be an amphibian. It is obviously a "border-line" form and represents a survival into the Permian of a group which may have been the fore-

runners of the early reptiles, a group that may have retained an aquatic larval condition and so been close to the embolomerous amphibia. Representatives of this group are hitherto unknown from South African deposits. The presumed common origin of all the early reptiles from one group therefore leads to one of the following theories regarding the place of evolution of the Cotylosaurs and Therapsids of the *Tapinocephalus* zone—either (1) they evolved from the earlier group near the present Karroo basin, (2) they evolved elsewhere, in the vicinity of the N. American-European land-mass, or (3) both the northern and southern assemblages of primitive reptiles represent migrations from some intermediate place of origin.

Theories (2) and (3) each presume that in some area two parallel lines of development were taking place, one leading to the Pelycosaur-Cotylosaur assemblage of North America and Europe and the other to the Pareiasaur-Therapsid fauna of Africa which—following the retreat of the Dwyka ice—migrated into the Karroo. The latter assemblage has left no traces of itself in the deposits of Central Europe and North America which, as Case has pointed out, are terrestrial deposits of limited extent and contain the remains of animals in close proximity to the places where they lived. The environmental factors, under these two theories, must have been similar for the two diverging lines; and had the two lines of evolution lain side by side in the one area, one would have expected to have found traces of the southern fauna in the northern basins of Carboniferous and early Permian deposits. It is, moreover, scarcely conceivable that from a single early stock two strongly divergent lines would arise under similar environmental conditions.

We are thus forced to adopt the theory that the primitive stock was scattered in its distribution and that, under differing environmental conditions, evolution proceeded from it in differing directions. In North America this ancestral stock must have been in existence in pre-Upper Pennsylvanian times, and we must therefore presume that the area in which the Karroo fauna began to appear must also have existed as land at the same period. If the habitation of this land (which apparently lay to the south and west of the present Karroo basin) by the ancestral stock was accomplished *after* the Dwyka glaciation, then the date of the glaciation must be placed early in the Carboniferous; if it took place *before* the glaciation, then the "land refuge" referred to earlier becomes essential. Since *Mesosaurus* is a specialised offshoot from the ancestral stock, that stock must have been in existence in pre-Upper Dwyka (i.e. pre-"White Band") times. The time-space between the close of the actual glaciation and the deposition of the White Band and Iraty Shales with *Mesosaurus* is presumably small and we are forced to demand a refuge for the pre-reptilian stock during the glaciation, a refuge free from ice, but with environmental conditions which permitted, or demanded, the production of reptilian types such as we find

in the basal Beaufort Beds. During Ecca times migration took place from this south-western refuge into the lands bordering the Karroo basin on the south; by the end of Ecca times the Karroo fauna had become established in its new surroundings, and continued to evolve there along already-determined lines, and to occupy areas further removed from its first place of origin.

Age of the Lower Karroo Beds.

Certain conclusions under this head follow from the remarks made above. It has been shewn that the stock from which the reptiles sprung must have been in existence in pre-Upper Pennsylvanian times, and—in the south—in pre-"White Band" times. Its occupancy of the southern land must have first occurred before the Dwyka glaciation of South America as (1) the time which elapsed between the close of that glaciation and the appearance of *Mesosaurus* seems too short to permit of the migration of the primitive group from the north and its subsequent development into a specialised type like *Mesosaurus*, and (2) it is inconceivable that the primitive group would have forsaken its adequate environment in the north to migrate southwards into a region that was ice-bound. At the same time, it must be accepted that the cooler conditions in which it found itself must have speeded up the rate of evolution and the formation of reptiles to whom such a cold environment was not deleterious; and we must consequently presume that evolution in the south was not more retarded than in the north. In the latter area, where external conditions were more adapted to the amphibian mode of life, it had reached a high degree of specialisation just before the close of the Carboniferous, and in the south evolution must have progressed at least as rapidly. On this line of argument it is not possible to agree with Schuchert's statement that the glaciation was Middle Permian in age; it becomes necessary to put the glaciation at the latest in the upper part of the Carboniferous. The Permian in South Africa is then represented by the beds lying between the base of the Ecca and the top of the *Cistecephalus* zone, most workers agreeing that the *Lystrosaurus* zone should be taken as the base of the Triassic.

Appendix.

THE FAUNA OF THE STORMBERG SERIES.

Although stratigraphically the Stormberg Series is grouped with the lower series in the one great Karroo System, its reptilian fauna differs from that of the Beaufort Beds in two important respects, viz., it is predominantly Diapsid and it bears a far closer relationship to the Triassic land fauna of Central Europa than is seen to exist between the Permian faunas of the two areas. Nevertheless, it is not isolated from the fauna of the Beaufort Beds but can legitimately be derived from some of the earlier components.

As interpreted by the present writer, the fauna comprises 3 species of Cynodontia, 4 species of Pseudosuchia, 24 species of Theropodous Saurischia, and one species of Ornithopodous Dinosaur. 21 of these forms occur in the Red Beds, and 11 in the overlying Cave Sandstone.

The Cynodontia are represented by skull or lower jaw fragments only, and are small forms shewing specialised dentition. It is not without the bounds of possibility that they may be mammals; but they can certainly be derived from Beaufort ancestors.

The Pseudosuchia are of considerable interest. The four known genera are *Sphenosuchus*, *Erythrochampsa*, *Notochampsa*, and *Pedeticosaurus*, of which the two former are from the Red Beds and the others from the Cave Sandstone. The Pseudosuchia of the Stormberg are almost undoubtedly derived through such a form as *Euparkeria* (Upper Beaufort Beds) from the Eosuchia, whose best known genus *Youngina* occurs in the middle of the Lower Beaufort Beds. In Triassic times the Pseudosuchia, in contradistinction to the Beaufort Synapsids, has an almost world-wide distribution, occurring as they do in North America, Scotland, Central Europe and South Africa. If their descent is to be traced back closely to a Karroo Eosuchian, then there must have been far closer connection between the S. African and Central European-North American land masses in Triassic times than existed during the preceding Permian.

The Stormberg Pseudosuchia are of interest in that they show well-defined crocodilian affinities. Broom, in fact, goes so far as to maintain that *Notochampsa* and *Erythrochampsa* belong to a family of true Crocodiles not far removed from the Lower Jurassic Atoposauridae; but von Huene and Haughton do not agree, although they are of opinion that these two forms, together with *Sphenosuchus*, are stages in the evolution of the Crocodiles. If the latter first appear in the Lower Jurassic, then the Upper Stormberg sediments cannot be later than Rhaetic.

The possibility of easy migration between Europe and South Africa in Upper Triassic times is also borne out by a study of the Saurischia. The genera occurring in the two areas are either the same or are closely allied, and the order of their appearance is apparently dependent on the environment. At any rate, in South Africa the heavy, large forms characteristic of the lower Red Beds—which were deposited under semi-arid conditions imposed on the swampy or wet areas which were the product of the deltaic conditions of Molteno times—gradually give place to lighter-limbed and more cursorial forms which accompanied the advance of aridity, an aridity which culminated in the desert conditions under which the Cave Sandstone was formed. In the inland basin areas of Central Europe the order of appearance seems to have been reversed. The light-limbed *Thecodontosaurus* ranges from the Lower Muschelkalk to the Middle Keuper; the larger *Gressly-* and *Platesaurus* occur in the Upper Keuper and Rhaetic.

The Chief Triassic element that is absent from the South African reptilian fauna is the suborder Phytosauria which occurs in rocks of the same age in India, Europa and North America. Adapted as they were for a subaquatic mode of existence, it is highly probable that the arid environmental conditions prevailing during the deposition of most of the Stormberg Beds forbade their dispersal into the South African region; and their absence therefrom cannot be considered as an argument against the land connection between the northern and southern areas in Upper Triassic times. If some member of the Pelycosimia be looked upon as the Lower or Middle Triassic ancestor of the Phytosaurs, then we may look upon the absence of the latter in the South African deposits as being directly due to the increasing aridity which drove them out into less unfavourable environments.

29. THE KARROO SYSTEM IN EAST AND CENTRAL AFRICA.

BY

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(Bulawayo.)

I. Introduction.

General. The widespread extent of the Karroo system in South Africa is in itself sufficient to mark it as covering an extraordinarily large area for a series of beds which appear to have been laid down under non-marine conditions. But when we consider their extension in the less known regions lying to the north and east of their development they certainly give rise to some misgivings as to whether their mode of origin is thoroughly understood. Indeed the possibility has to be faced of conditions having prevailed on an almost world-wide scale of which there is no counterpart at the present time, or alternatively of some remarkable combination of circumstances having led to a distribution of land and sea over very much the same areas in Karroo times as at the present day. Even in Europe the Permian, and New Red Sandstones generally, indicate continential conditions, and it was only in Jurassic times that normal marine deposits became more prevalent in the Northern Hemisphere while south of the Equator great volcanic outpourings took place, which also heralded a certain amount of encroachment of the sea over the land. If, therefore one postulates the existence of the once fashionable Gondwanaland, the implication is that there was more land than sea in the Southern Hemisphere if not over the entire world. The glacial episode in the Tropics and the presence of the Glossopteris flora in the South Polar regions open up a still more extensive vista of pysiographical problems, and compels one to speak respectfully of Osmond Fisher's conception of continental drift, now for some reason generally known as Wegener's hypothesis.

The present paper has not, however, for its object the discussion of these problems, interesting as such speculations may be, but to put on record certain observations as to the extent and character of the beds in some of the less known parts of the continent, made in the course of the author's professional work. These include traverses and often fairly lengthy examinations of most of the occurrences south of the equator on the eastern part of the continent, with the exception of the areas round Lake Nyasa, though

I have had the opportunity of studying the collections of the Nyasaland Geological Survey through the kindness of DR. F. DIXEY, to whom I desire to tender my very heartiest thanks for his kindness during my visit.

Conditions of deposition. North of the Limpopo-Zambezi Watershed the general facies of the Karroo beds is very unlike that of the typical area in Cape Colony. There is good evidence that, in the region with which we are here concerned, the Karroo beds were deposited as a sequel to a prolonged period of denudation, so complete that only rarely are there any relics of older sedimentary formations between the Karroo strata and the crystalline rocks. There was certainly no Carboniferous sea as at the Cape and over most of Australia. The formation of the rocks here seems to have begun when denudation had almost succeeded in reducing the greater part of the area to a dead level, a state of affairs which the formation of coal seems indeed to demand.[1]) This period of erosion clearly continued throughout the Dwyka period, for although the well known glacial beds which form the basal position of the Karroo system in the Union of South Africa certainly cross the Limpopo into Bechuanaland,[2]) and probably also a short way into Southern Rhodesia,[3]) it may be stated, subject to this reservation, that they are absent from the Karroo system as developed in British Tropical Africa. The coal-bearing portion of the system, which is such a persistent feature throughout most of the area and renders it of much economic importance, usually lies at or near the base in the two Rhodesias and in Portuguese East Africa. In Nyasaland, however, a change begins to make itself apparent, and the coal-bearing, or perhaps more correctly, the carbonaceous beds, become more and more definitely located in the middle part of the system, as is the case at the northern end of Lake Nyasa [4]) and is very marked in Tanganyika territory, and where the strata cross its Northern border into Kenya. This may imply that conditions became favourable for the deposition of carbonaceous material at a later and later date as the beds are traced northward, though this is not altogether certain, as will be seen later. The present geographical situation of the areas seems influenced more by folding or faulting and subsequent denudation of what is now the plateau than by anything that can still be traced of original discontinuity, though there are places where ridges seem to have existed in early Karroo times; indeed the existence of a mountainous area within the tropics during the Dwyka epoch is a plausible speculation. If such was the case it had certainly been greatly reduced by the time the lowest beds began to be deposited in our area and even the most subdued features had been

[1]) F. P. MENNELL, Geol. of S.A. (1904).

[2]) H. B. MAUFE, Trans. G.S.S.A., Vol. XXV, 1922, p. 68.

[3]) F. P. MENNELL.

[4]) See ANDREW and BAILEY, Q.J.G.S., 1910, p. 213; and DIXEY, T.G.S.S.A., 1926, page 59.

reduced to vanishing point before the end of the period. Above the coal-bearing strata come beds which are probably of fresh water origin, though the occurrence of salt may be noted at certain points, as in the Madumabisa shales of the Wankie district (Southern Rhodesia), and on the Zambesi in the Tete district, probably on much the same horizon. The Madumabisa shales also shew a recurrence of coal-bearing conditions near their base, though the coal is not of workable quality. The Escarpment Grits are a very characteristic feature of the succession above the Madumabisa beds in the Wankie district and throughout northern Matabeleland, as well as in Northern Rhodesia, where they figure very conspicuously in the physical geography of some of the Zambesi tributaries. They are not, however, recognisable in the south of Southern Rhodesia, nor in Portuguese Territory, Nyasaland, or Tanganyika. They have the peculiarity of containing scattered pebbles which do not follow lines of bedding, and resemble in this respect the late Tertiary Inyaminga grit of Portuguese Territory which is clearly of marine or estuarine origin. A great change evidently took place after their deposition. The advanced stage of denudation which had been reached culminated over a large area in arid if not desert conditions.[5]) This was the case over most of Southern Rhodesia, and apparently in Northern Rhodesia, as well as in the northern part of the Mozambique Co.'s territory. During a visit to Nyasaland last year the fact that it was indicated by the survey specimens was pointed out to Dr. DIXEY. Below the topmost sandstones characterised by windworn grains there is often a well marked zone with abundant silicified wood, noticeable both in Northern Rhodesia,[6]) where the beds are comparatively thin, and in Nyasaland where they are of great thickness, as well as in Southern Rhodesia. There is, however, both in Northern Nyasaland and in Tanganyika an important difference in the character of the upper beds, which are there very thick and contain shales and even limestones[7]) instead of the typical aeolian "Forest-Sandstones" of Southern Rhodesia, which nowhere much exceed 200 ft. in thickness. This may be well seen along the Kenya and Tanganyika border where the beds extend right into the sea. They were perhaps in part deposited while the Karroo basalts were being poured out elsewhere, as the lavas do not occur in the same areas, except possibly near Lake Tanganyika. The Desert episode in parts of Northern Rhodesia may have been brief, judging from the very small thickness of the beds which resemble the Forest sandstone[8]) in the Kafue area, but that it reached far into the north is shewn by Dr. DIXEY's discovery of aeolian sandstones in the upper Luangwa valley,[9]) and there are also sandstones in the Rufigi region of Tanganyika which may be windworn. The topmost beds in the

[5]) F. P. MENNELL, Q.J.G.S., Vol. lxvi, 1910, p. 367.
[6]) Below the Escarpment Grits.
[7]) F. DIXEY, Trans. Geol. Soc., S.A., Vol. xxix, 1926, p. 61.
[8]) F. P. MENNELL, Geol. Mag. 1922, p. 168.
[9]) Ann. Rep. Nyasaland Geol. Survey for 1928, p. 12.

Mozambique Co's territory are only exposed as a very narrow strip along the boundary fault under the basalts between Gorongoza and the Pompue river, the basalts coming right up to the fault in other places. The uppermost sandstones often have extraordinary unequal sized grains, the larger ones being sometimes of very irregular shape, but even these beds shew plenty of windworn grains, especially amongst the finer material. Even if it includes the greater part of Portuguese East Africa, the Karroo desert was not much larger than the present Kalahari, which it must be remembered is a decreasing area, as shewn by the relics of the Kalahari sand over a large part of Rhodesia.[10]) The conditions prevailing at a period just antecedent to the outpouring of the Karroo basalts may therefore be pictured as remarkably similar to those of Africa at the present day. The Somabula gem-bearing gravels near Gwelo, which the evidence of the plant remains necessitates our considering as of late Karroo age, represent a very interesting record of fluviatile conditions, possibly paralleled by such rivers as the Okavanga at the present day.

The basalts of which the outpouring marks the close of Karroo times are as widely developed in Rhodesia, both north and south, and in Portuguese territory as in the Drakensberg, though probably not as thick, and shew the same uniformity of composition. The (Jurassic) Lupata sandstones by which they are succeeded in Portuguese territory do not always shew marked signs of discordance, but their basal beds contain plenty of material derived from the underlying lavas. The last may have some rhyolites at their top in places, but these on the other hand may belong to the upper part of the Jurassic or lower part of the Cretaceous period.

Distribution. The Karroo areas which are so extensive in the low country on both sides of the Zambezi, become much reduced in size further north, only widely separated patches occurring in Angola, the Belgian Congo, Tanganyika, Kenya, Nyasaland, and Portuguese Nyasaland. Until more detailed mapping is carried out, and possibly assisted by more artificial exposures than at present exist, it is difficult to be certain of the real nature of the observed discontinuities. Thus in some of the best known localities, such as those flanking the Matebeland plateau, it is by no means clear what is the precise nature of the overlap of the basalts and underlying Forest sandstones (Stormberg series) on to the old rocks of the high country. It may be merely the result of greater extension of those beds due to the silting up of the lakes and swamps in which the lower part of the system was laid down, but it may, on the other hand, have taken place after a certain amount of elevation and denudation of what is now the plateau. At the same time it must be admitted that the desert conditions under which the upper beds were deposited may be held to indicate long continued quiscence prior to

[10]) See Du Toit, Rep. S.A.A.S., 1927, p. 90.

their deposition, a state of affairs terminated by the widespread but only locally orogenic movements which were accompanied by the emission of the Karroo basalts. In any event the present disconnected distribution of many of the areas is clearly due to subsequent erosion and is not any indication of their original extent. There might for instance appear at first sight to be some significance in the basalt being restricted to the low country in Portuguese territory and along the Sabi Valley on the Rhodesian side of the border. This is, however, the result of post-Karroo faulting, as indeed the great height of the Shimamanimani and Melsetter mountains would cause one to suspect, and the lower part of the Karroo system is actually represented just on the border on the upthrow side of the Mosurise fault. In a similar way the disconnected areas of Karroo beds in the Luano plains and in the valleys of the Lufua and Lusito rivers near the Zambezi were obviously continuous right on to the plateau and their present discontinuity is due to denudation super-imposed, not, as Molyneux originally suggested,[11]) on folding, but on a very interesting series of stepfaults. In fact owing to the softness of the beds as compared with the old rocks on which they rest, their preservation is almost everywhere due largely to their having been sunk by folding or faulting below the base level of the main river systems. This is especially the case with the lower divisions of the Karroo, which never reach the plateau in either Southern Rhodesia or Portuguese territory, and very seldom do so elsewhere.

Some of the areas that have been referred to are fairly well known, and the writer has therefore confined his account to the less known regions with which he is personally acquainted.

II. Mozambique Company's Territory.

The structure of the Karroo beds in the part of Portuguese territory under the administration of the Mozambique Company lying to the east of S. Rhodesia is simple in the extreme. They are confined to two long and relatively very narrow strips, apparently bounded on the western side by almost continuous lines of fault, which generally bring the basalt into direct contact with the ancient gneisses and granites of the interior. They consistently dip at low angles, in a more or less easterly direction, and they are thus overlain on that side by younger sediments of marine origin, of which the oldest are possibly Jurassic, and those above certainly of Cretaceous and Tertiary age. All these sediments form one limb of the great geosyncline marked by the Mozambique Channel, of which the other limb appears in Madagascar, which shews a corresponding sequence, though it does not appear to include the basalts.

[11]) The Karroo System in Northern Rhodesia. Q.J.G.S., pp. 411, 419, 433, etc., Vol. lxv, 1909.

Northern Strip. The northern strip is just about a hundred miles in length, and runs very nearly north and south from the Intaduhe (Incadue) river to the Muira, not far from the Zambezi. Its width is commonly six to eight miles, and the Karroo sandstones are only exposed for half the length of the strip, that is to say for about fifty miles south from the Pompue river. On the South bank of the Pompue the boundary fault can be well seen, just at the northern termination of the narrow strip of sandstone: it is vertical, and runs 5° West of N (true). A curious point is that less than twenty miles further north the basalts can be actually seen overlying the gneiss directly. A similar feature is of course to be observed west of Wankie, where gneiss emerges from beneath the basalt near the Deka river, although the complete Karroo sequence is exposed on the other side of the fault, only a few miles away. The average width of the strip of sediments is probably about half a mile. The widest point is at the Sangadzi river, which has removed the basalts from above them for a width of over two miles, while the section seen along the Hata, a tributary of the Inyamapaza, is about a mile across. The beds are predominantly arenaceous, though soft shales are seen in the Sangadzi section, and reddish rather pebbly mudstones are the lowest beds exposed in the vicinity of the Hata river. Immediately below the basalt there is often a cherty or agate-like layer similar to that seen under the lowest flow in the Rhodesian area near Bulawayo. The sandstones themselves are, however, not at all like the Rhodesian Forest Sandstones as a rule in the field, the only exception that I am aware of being a thin seam of rather buff-coloured fine material reminiscent of the beds in the Sabi valley in south eastern Mashonaland, which occurs very near the western edge of the Hata section. The beds under the lavas near Tondo on the Sangadzi river, and near Pangatala, further north, are composed, as seen under the microscope, of grains which are extraordinarily uneven in size, and of which the largest are also often extremely irregular in shape. They have, however this important character in common with the Forest sandstones, that the bulk of the material is undoubtedly windworn, the freshness of the abundant felspar bearing out the inference based on the rounding of the grains.[12]) There are lower strata, like those nearest to the gneiss in the Sangadzi section, with more uniform sized and closely packed material, in which the felspar is always more or less kaolinised, which resemble the lower Karroo sandstones, but these are not seen elsewhere owing to the extreme narrowness of the Karroo outcrop alongside the boundary fault. At both the north and south ends of the belt the lavas are the only representatives of the Karroo, and they themselves eventually disappear owing to the overlap across them of the Lower Lupata sandstones which are probably of Jurassic age. It is an interesting point that the Karroo sedi-

[12]) This is especially striking in the finer material which is of far less dimensions than the limit of 1/10 mm. given by Danby for water worn grains.

ments here are often penetrated by dykes and sheets of dolerite, in striking contrast with the fact that in Rhodesia not a single intrusion of dolerite is known among these strata, though many presumably of Karroo age occur amongst the older rocks. For instance there are three dolerite dykes in the Sangadzi section already referred to, and at least ten in that along the Hata river.

The lavas are basalts of typically Karroo aspect, both in the field and under the microscope. They not infrequently have interbedded layers of sedimentary and apparently also tufaceous material. For instance at Canxixe (Kanshishi) there is a limestone with patches of chert, near the top of the basalts as there exposed, and a similar rock occurs near Inyamasensense, south of the Inyamapaza river. The latter may be on the same horizon, as although it is covered by several flows of lava, the exposed width under the Lupata sandstones is there greater than at Canxixe, which is on somewhat higher ground. At the same locality there are also at least two intercalated beds of sandstone. The finer and harder on higher horizon than the limestone, and the other, which is coarse and felspathic, lower down in the series, of which it is still rather above the middle. It is well seen on the bank of the Hata river.

Sections have been examined of specimens collected at various localities, and they are basalts of remarkably uniform character. One from Bonga representing the lowest flow at the extreme northern end of the area, is a fine grained aggregate of augite grains and felspar laths. It is quite free from glass, and contains a fair amount of magnetite in grains which have almost the character of ophitic plates, as they are larger than the other constituents and of late consolidation. At the Pompue the lowest flow seen alongside the fault is very crushed and otherwise altered; it is as coarse in the middle as an ordinary dolerite. A specimen from the foot of Mt. Dzunji is rather coarse and holocrystalline, while another from further south at Fomantinta's on the Inyaruwiro R. is even coarser in general grain, but contains an appreciable amount of glass nearly opaque with magnetite dust. From the bed of the Sangadzi river a carefully selected specimen of the freshest and coarsest variety obtainable from the middle of one of the flows in the middle of the series, proved to be very like an ordinary dolerite. It has a little glass full of magnetite skeletons, as well as some larger grains of magnetite or ilmenite of rather late consolidation, and there are a few greenish or brownish patches of alteration products which may represent olivine. Apart from this somewhat doubtful record, the mineral is absent from all the specimens sliced. At Canxixe several specimens were collected from the flows immediately under the covering of later sediments. The coarsest is very like that from the bed of the Sangadzi, but it has a few glomeroporphyritic aggregates of felspar, and is free from the larger grains of magnetite as well as the olivine pseudomorphs, if such they be. A finer variety from the garden at the small stream near the ginnery is holocrys-

talline in spite of its fine grain. It shews glomero-porphyritic felspars, and rather sparsely distributed magnetite in small grains of late consolidation. Another specimen from the track to Tondo is very fine but quite different in appearance, being made up of sharply defined small felspar laths and magnetite grains scattered through a base with scarcely any effect on polarised light.

Southern Strip. The southern strip of Karroo Basalt runs from the Rhodesian border near the junction of the Lundi with the Sabi river, in a north-easterly direction as far as the Makudzi river in the vicinity of Villa Machado, a distance of 160 miles. The dip of the lavas is south-easterly, so younger sediments come in towards the coast, but along the Sabi fault across the Rhodesian border where the downthrow is in the opposite direction, the complete Karroo sequence, including the coal beds, is seen below the basalt. On the Portuguese side of the frontier the only outcrop of the sediments is a small patch near the border on the upthrow side of the fault, discovered by Messrs. Teale and Wilson. This is of importance as demonstrating that the sediments really exist under the basalt, and that the throw of the fault is a considerable one. It will be realised that though they make such a small show on the surface in the territory, they evidence the existence of a very extensive area buried under the younger rocks stretching to the coast, of which the basalts approach within 60 miles at their nearest point. The width of outcrop of the basalts is fully eight miles near the Mosurise River, close to its confluence with the Buzi, and very much the same on the road to Grudja, near the Musikavu river. The nearly straight course of the basalts is interrupted on the east side of the Shimanemane mountains, round which they appear to swing, as suggested by specimens sent to me some years ago by Mr. C. F. M. Swinnerton. This is probably due to a cross fault in a nearly N and S direction near the foot of the hills. The basalts are intersected by many intrusions of olivine dolerite, and it is by no means certain that these are of Karroo age: it is very probable, in fact, that they are of later date. A very interesting feature of the gneissic area adjacent to the basalts is that it is penetrated, not only by numerous dykes of dolerite, most of which are clearly of types related to the lavas, but by masses of volcanic breccia which probably indicate the sites of Karroo volcanoes. They are no doubt numerous, as several were noted in a single traverse of a few miles along the Muda—and near that river. What may be a bed of ash was also noted among the lower part of the lavas on the edge of a small stream about a mile south of the Mutwa river. The lavas of the southern area are not quite so normal in type as is the case in the northern strip. Some it is true have the normal fine-grained doleritic appearance with glomero-porphyritic aggregates of felspar, but others do not conform so closely to the ordinary Karroo pattern. Thus there is exposed in the bed of the Mutwa river immediately alongside the

gneiss a very basic rock which agrees with the other flows at this point in being penetrated by dolerite dykes. This closely approaches the limburgites in character, being largely made up of porphyritic crystals and aggregates of olivine, a mineral which is of rare occurrence among the Karroo lavas to the north and west. The groundmass is very fine but holocrystalline, being made up of augite grains and felspar laths, with the former predominating, together with a little magnetite of late consolidation in very irregular strings. The highly amygdaloidal flow above this is rather coarse and without porphyritic elements, being made up of laths of felspar up to a mm. in length, together with augite grains and a little glass containing skeleton crystals of magnetite. At the Chindu river, a few miles further south, flows considerably higher up in the succession are exposed, and they are of more usual types. One with large sparingly distributed amygdales has a very fine altered groundmass in which are scattered numerous fine glomero-porphyritic patches of felspar or individual felspars and occasional patches of coarser material consisting of felspar laths and some augite granules together with a certain amount of brownish glass containing skeleton crystals of magnetite. A lower flow from this locality has in its central portion a coarse glomero-porphyritic character, the holo-crystalline groundmass much resembling the finer Karroo dolerites. Away to the south-west on the Grudja road, the coarsest and freshest type seen, that exposed in blasting for the foundations of the bridge across the Musikavu river, is an even grained rock just like the non-ophitic dolerites. It contains much magnetite of late consolidation. Some miles south of the Musikavu, several specimens from higher flows were collected. These usually contain abundant porphyritic augite, often in glomero-porphyritic aggregates with or without felspar. They often have a considerable proportion of glass, in which case the minute magnetite grains are entirely restricted to the glass. All the last mentioned rocks are free from olivine.

III. Northern Rhodesia.

Distribution. The basaltic area which is well known in Southern Rhodesia runs far up the Zambezi where it forms the Gonve Falls as well as the far more imposing Victoria Falls, with their width of a mile and a quarter, and a drop of 400 ft. As regards its northern boundary, practically no addition has been made to our knowledge since the traverse of Mr. G. W. Lamplugh in 1905. His map [13]) is clearly erroneous, however, in depicting a wide belt of sediments between the volcanics and the granite of the Kalomo plateau. As may be seen from the train between Senkobo and Makoli sidings, the granite comes in immediately after passing off the basalt. North of Livingstone the dip slope and escarpment-like character of the basalt hills is very

[13]) Q.J.G.S., Vol. lxiii, 1907, pl. xvii.

apparent to the eastward, and clearly indicates the large number of the flows. The dip is southerly and this taken in conjunction with the northerly dip on the other side of the river shews the synclinal character of the Zambezi valley in this part of its course. Beyond the basalts the granite and other ancient rocks appear immediately: whether this is due to faulting or to the dying out or erosion of the sediments there has been no opportunity of determining.

Downstream, the Zambezi, after crossing the Deka fault, runs in either the old crystalline rocks or the Karroo beds for a long distance, in fact most of the way to the Lupata gorge, and where in the crystalline rocks usually has the Karroo beds or the overlying basalts not far distant. Along some of its tributaries, in fact, and notably in the basins of the Lufua and Lusito rivers, extensive areas of Karroo strata are seen,[14]) though curiously enough the basalts are nowhere observed above them, except at one point near the Kafue,[15]) where, on the other hand, the lower part of the system is not seen. Further north, the Luano plains and the valleys of the Luangwa and Lukashashi rivers afford other exposures of the strata, always in low-lying areas where they have been preserved largely by faulting.

Structure. Though there is no actual evidence as to the nature of the junction, it is probable from the structure of the lower part of the Karroo in the Zambezi basin that a ridge of ancient rocks existed in Karroo times running in a direction north of east by south of west across the country now traversed by the Kafue in the part of its course round about the railway bridge. This high ground would thus run parallel to the present courses of the Zambezi from Livingstone to Feira, and to the axis of the Southern Rhodesian plateau.[16]) Without going deeply into physiographical speculations it may be further stated that the upper portions of both the Zambezi and Kafue seem unquestionably to have flowed originally into the closed basin of the Kalahari, and the lower courses of both represent streams which, during the long period of post-Karroo subsidence culminating in Eocene times,[17]) beheaded those and other south flowing streams. The Gwaai river in a similar way beheaded all the westward flowing rivers of North Matabeleland with the exception of a few in the extreme west, which still flow into, and lose themselves in the Kalahari.

In his paper of 1909[18]) Molyneux, as previously noted, stresses the synclinal structure of the strips of Karroo beds in Northern Rhodesia. This, however, fails to explain the fact that the uppermost beds of the Karroo,

[14]) A. J. C. MOLYNEUX, Q.J.G.S., Vol. lxv, 1909, p. 4.
[15]) Geol. Mag., Vol. lix, 1922, p. 167.
[16]) F. P. MENNELL, Geol. of S.R., 1914, p. 9 and fig. 1.
[17]) Evidenced by the occurrence in Portuguese Territory of extensive areas of nummulitic limestone.
[18]) Q.J.G.S., Vol. lxv. p. 408, etc.

including the Escarpment Grits, continually abut against the ancient crystalline rocks. The writer was only able to traverse the high ground overlooking the Luano plains, owing to the prevalence of the sleeping sickness which is a serious bar to its exploration, but the remarkable panorama that can be seen shows the emergence of ridges of the old rocks from the flatter sedimentary areas. In the case, however, of the region south of the Kafue he was able to make, not only extensive traverses, but detailed investigation of more limited areas which left no doubt as to the nature of the structure. In these the strata have everywhere a general south-easterly dip only locally departed from to any great extent. Their disposition in long narrow belts running across country in a nearly north-east and south-west direction is due to a series of at least seven nearly parallel faults which divide the strata up into strips let down amongst the older rocks. The lowest beds can be seen dipping at angles like 15° or 20° or even more to the south-east along their north-west boundaries and their position normally overlying the ancient gneisses, &c., can be verified in many river sections. The steep descent from the plateau can thus be seen to represent substantially the tilted basement on which the Karroo beds were laid down, and is not a true escarpment. On the opposite side, however, the Escarpment Grits, or the underlying grey shales, abut against the Gneisses and other old rocks, and well marked crush-breccias are seen at the junction: in one instance the author was able to walk for miles along the fault rock, every turn of the path to the left bringing him on to the sediments, while each swerve to the right brought him on the gneiss. The faulting clearly took place during or after the assumption of a synclinal structure by the whole area occupied by the sediments and its effect has been to constantly interrupt it and neutralise the tendency of the beds to reach a lower level, so much so that the Zambezi iself at the Kariba gorge flows in the ancient gneisses brought up by the seventh successive stepfault. It is extremely probable that the movements affecting the Karroo here were mostly of late Karroo (i.e. Stormberg) age as there is no indication of the great basalt areas of Matebeleland being chopped up by faulting in the way that seems to be the invariable rule with the sediments below, up to and including the Escarpment Grits. This is in line with the fact that in Portuguese Territory pebbles of the characteristic siliceous Karroo fault rocks can be frequently picked up amongst those weathered out from the overlying Lupata (?Jurassic) sandstones. It will be noted that the direction of the boundary faults of the Wankie coalfield and the strip running through Inyantue siding to the south of it are parallel to the faults in this area though the general dip is in the opposite direction, and the same remarks apply apparently to the Luano area where the dominant direction of the dip seems to be west of north as at Wankie. It is rather curious that a straight line drawn from Wankie to the Luano plains would pass right through the Karroo areas on the Lufua and Lusito. The direction of this line is, however, distinctly north of north-east while that of the Deka fault

and the faults in the Lufua coalfield is distinctly east of north-east, the same being the case in the Luano area if STUDT can be trusted.[19]) It seems therefore that two parallel folds can be traced having very much the same direction as the course taken by the Zambezi in this region, the great river itself occupying one syncline, while the Luano plains seem to mark the southern side of a second syncline preserved by the fault which MOLYNEUX recognises as forming its Northern limit. Both these folds are of course much modified by the remarkable series of faults running along the strike, and also to a less extent by faulting in other directions. Further work may show that they conform more closely to the Wankie model than at present appears. It will, of course, be realised that the faults may be neither so straight nor so nearly parallel as represented, but they indicate the position as closely as it could be worked out in the absence of any reliable topographical map, though since my observations were made I have had somewhat better data supplied me owing to the kindness of Mr. W. S. FAIRWEATHER.

Subdivisions of the Strata. The subdivisions enumerated at Wankie do not altogether hold good in Northern Rhodesia, and as a matter of fact the strata vary so much from point to point even at very short distances apart that any general classification is bound to be unsatisfactory. The following will, however, serve to indicate the relationship to the Wankie development.

Zambezi Basalts (apparently at one point only, north of Falls area).

Forest Sandstones (apparently at one point only, north of Falls area) about 50 ft.

Escarpment Grits, probably 500 or 600 ft. (well and typically developed but top and base not seen in any one area).

Upper Shale Series, with mudstones, sandstones, concretionary limestones, &c., and silicified wood. About 200 to 300 ft.

Black shale and Coal Series, (shales not black in some places, even where good coal seams.) About 200 ft.

Lower Sandstones and Basal Conglomerate (sometimes entirely absent). Up to 200 ft.

This compares fairly well with the succession in the Luano plains as given by STUDT from records of boring,[20]) which may be tabulated as follows:

5. Light coloured sandstones and grits, about 600 ft.
4. Light coloured sandstones with limy concretions, about 300 ft.
3. Brownish sandstones, grits and conglomerates, about 200 ft.
2. Dark clays and shales with coal, about 200 ft.
1. Basal breccias, conglomerates and red clays, about 200 ft.

[19]) See Trans. G.S.S.A., Vol. xvi, 1913, pl. xiv.

[20]) Trans. G.S.S.A.. Vol. xvi, 1913, p. 62.

Studt also refers to a very thick upper series of pebbly grits and coarse sandstones having a predominantly brick red colour.[1] Of these beds Molyneux makes no mention whatever: from his account the 5th division as given above is evidently the Escarpment Grit.

Coal Shales, &c. The lowest division is extremely variable in importance and its two sub-divisions dovetail into each other. One may be present to the complete exclusion of the other, while in some cases the coal shales may be considered as resting directly on the old gneisses, crystalline limestones, etc., having only a few feet in the nature of a "dirt-bed" under the lowest coal seam. Looking through my notebooks such bewildering differences are recorded in sections quite close together both in these beds and those higher up as to demonstrate how extremely variable they are. For instance along the Chigalonto river, above its junction with the Lutembo, the black shales are at least 200 ft. thick and contain numerous seams of coal up to 11 ft. thick, as well as ironstones up to 6 ft. in thickness. The underlying beds are seldom 20 ft. thick and consist of mudstone, ferruginous grit, etc. usually with a foot or so of conglomerate at the actual base, this last consisting almost entirely of large and small fragments of quartz. The underlying floor of crystalline rocks usually consists of limestone and associated beds, or else of biotite-kyanite-schist, these types of rock having a very wide distribution in this part of the Zambezi basin. A short distance to the east, about a mile down the Lutembo river from where it is joined by the Chigalonto, there are thick beds of coarse grit and quartz-pebble conglomerates below the coal shales and they must be at least 100 to 200 ft. thick. There was no opportunity of closely examining the sections of the lower beds passed in a somewhat hasty traverse along the Lufua but further away to the east on the Lusangashi river there are no black shales at the highest point upstream where the sediments are seen. There are only two seams of coal, each about 4 to 5 ft. in width and they occur in grey shale like those usually seen above the coal-bearing series. The river follows the margin of the sediments for some miles. Further down reddish and chocolate shales occur below the coal seams: there is some concretionary ironstone and limestone in the shale but no grits are seen, the shales resting directly on the old rocks. There appears to be 60 or 70 ft. of shale below the coal. Further down still, the base of the Karroo consists of dark brown shale or mudstone. This is succeeded by grey and brownish shales, and these again by black shales of which 20 or 30 ft. intervene before the two coal seams come in. On the Kasiwa, a tributary of the Lusangashi, the basement rocks under the Karroo are coarse white gneiss succeeded by flaggy schists with biotite, actual coal outcropping less than 100 yards away. In some of its tributaries the lowest beds are exposed: there are no signs of the chocolate or brown shales seen in the Lusangashi while on the other hand there are basal sandstones with sparse pebbles, not many feet thick, however. The adjacent hills

of gneiss, crystalline limestone, etc., look so steep that it appears as if there must be a fault to prevent the Karroo beds being found upon them. Actual measurement, however, showed that the slopes of Natisoma, the steepest point in the foreground, were only 17° on the lower part of the hill, attaining a maximum of 25° towards the top. The Karroo on the other hand dipped at 30° at this point. These facts are recorded, as imperfect observations unchecked by measurements might well lead to the assumption of faulted boundaries, especially where, as at this locality, there are numerous signs of small faults in various directions which do not however appear to affect the general structure. It may be mentioned that my companion guessed the slope as 45°. No recognisable fossils have been found in any of these areas, though obscure plant remains are abundant. As will have been seen from the descriptions of the sections the coal itself sometimes forms numerous seams, while in other places there are but two. The character of the coal varies somewhat: some seams are of poor quality with a high ash content, but it always cokes well and is so bituminous that even where it has 40% of ash it will ignite quite as easily as wood. It may be piled up on the ground to make a camp fire and lit with a bundle of grass. The ironstones that have been referred to are of somewhat lenticular character, but range up to quite 6 ft. in thickness. A sample from a cliff section on the Chigalonto gave an analysis 26% of metallic iron with 25% of silica. It may be mentioned that the crystalline limestone which often forms the floor on which the Karroo beds rest is quite unlike the highly dolomitic Broken Hill limestone which latter is no doubt the equivalent of the Sinoia limestone of Southern Rhodesia and the Transvaal dolomite. It may also be noted that limestone, coal and ironstone of good quality all occur within a thickness of 50 ft. of strata at one point.

Upper Shales and Escarpment Grits. Almost everywhere the dark coal shales are succeeded by light coloured, usually pale grey, shales and mudstones, which are often very uniform throughout. Sometimes, however, there are beds of brownish sandstone and micaceous grit intercalated amongst them as may be seen for instance in the Lutembo area. Concretionary seams of limestone are not uncommon and are well seen at several points along the banks of the Lufua river. Silicified wood occurs in these beds in some abundance at various localities. Near the Lusangashi River pieces can be picked up full of holes made by boring insects and looking so exactly like ordinary bits of decayed timber that their weight always gives one a sensation of surprise. It is sometime almost impossible to draw a dividing line between the upper shales and the underlying coal beds, which may be equally pale in colour. They are very poorly exposed as a rule except along some of the scarps where they are protected by hard cappings of Escarpment Grit. The latter is very well developed and though the thicknesses seen on most of the scarps are very much less, there are places where they must be at

least 500 to 600 ft. thick. Mt. Chisari which rises from the Bonda flats south of the Lufua river gives one the impression of having an even greater thickness, but the author was not able to do more than observe it from a distance. It is probable, therefore, that the beds are as thick as at Wankie where they must be at least 600 ft. the Survey estimate of 300 ft. being, as already mentioned, altogether too low. It has already been recorded that they are about 600 ft. thick in the Luano plains, so that they maintain a very uniform character for a distance of at least 300 miles in a N.E. S.W. direction.

Forest Sandstones and Basalt. Throughout the Lufua-Lusito and Luano coalfields there are no signs of the Forest Sandstones or basalts capping the Escarpment Grits. This might very well cause their original absence to be inferred but Wankie affords a warning that this is not a very safe conclusion, and that it would be incorrect is clear from the fact, first determined by the writer in 1920, that they both occur with the underlying Escarpment Grit close to the Kafue along a small tributary of that river called the Kesha. The succession there as determined from sections in some small streams is as follows:—

Basalt	6 or 7 flows. Fully 500 ft., top not seen.
Forest Sandstone	Soft pinkish sandstone, unbedded, 30 ft. Bedded red sandstone, about 5 ft. Red sandstone with spheroidal weathering, about 10 ft.
Passage bed	Ferruginous sandstone, 4 ft.
Escarpment Grit	Hard, almost quartzitic, sandstone, becoming pebbly in lower part, about 100 ft. seen.

One of the most interesting points about this section is that the Forest Sandstone appears to shew a passage into the Escarpment Grit through the somewhat ferruginous bed mentioned above. The overlying lavas preserve the remarkable constancy of type that is so striking a feature of the Karroo eruptions, being basalts with nothing to distinguish them in thin section from the flows near Bulawayo. They are, in fact, distinctly more like the lavas on the edge of the Matabeleland plateau than those of the Victoria Falls. This may at first sight appear surprising, but it has to be remembered that the Kesha flows, like those near Bulawayo, belong to the base of the series, while at the Falls higher horizons are undoubtedly represented. Another very interesting point about this outlier is the light it throws on the past physiography of the region. From the railway bridge the Kafue actually drops more in the sixty miles which it has to flow before it joins the Zambezi than the latter river does from above the Victoria Falls to the same point, a matter of three hundred miles. Yet there is no great fall anywhere

on the Kafue, in fact none of more than a few yards. This outlier is however strong evidence that the Kafue has only recently finished the removal from its course of a mass of basalt quite comparable with that of the Falls, and it requires no great stretch of the imagination to see that a similar fall must have once existed here.

IV. Tanganyika Territory, Kenya and Nyasaland.

Introductory. In the this region, the most northerly to be dealt with in the present paper, and one reaching as far as the Equator, the Karroo beds cover a number of isolated tracts, three of which are near the coast, while the others are in the great geo-synclinal area which contains Lakes Tanganyika and Nyassa. Of the coastal occurrences, one is situated opposite the island of Mombasa, extending nearly as far as Tanga towards the south and an unknown distance to the north. Parts of it have been described by H. B. Maufe,[21]) E. O. Teale,[22]) E. Parsons [23] and others. The inland termination is probably a fault. Another strip of Karroo beds, nearly 100 miles long, emerges from beneath the intervening younger sediments south of the Central railway, apparently along a continuation of the same line of faulting. A third smaller tract occurs on the upthrow side of the fault (if such it be) on the west side of the Uluguru Mts., some little distance from the last mentioned area. All these have been examined by the writer, who has also visited the largest of the remaining areas, namely that along Lake Tanganyika near Ujiji, which stretches a considerable distance towards Lake Victoria. The rocks of that locality may and probably do, include both pre- and post-Karroo beds, some of the strata having a very ancient appearance, while others are certainly very different from most of the beds known in the Karroo elsewhere. It is also a fact of particular interest that the Karroo basalts are possibly represented, though there is a gap of no less than 800 miles between their southern end and the nearest of the areas in the Zambezi basin, which are along the 16th parallel of S. latitude.

Border area. This tract of sediments is of considerable interest for several reasons. One is the problem connected with the thickness of the strata. Others are the fossils, especially the plants, and the fact that the beds are overlaid by marine Jurassic sediments both along the Uganda railway and to the north west of Tanga on the Tanganyika side of the border. Ammonites etc. have been recorded from the shales of the mainland opposite Mombasa, while at Amboni on the Siji river there is a hard fossiliferous limestone, oolitic in places, dipping S.E. at 10° or more. This is believed

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[21]) Rep. rel. to the Geol. of E. African Prot., Misc. Col. Rep., No. 45, 1908.

[22]) See especially Geol. Mag. 1922, pp 385-8, and Mining Mag., June, etc., 1928.

[23]) Trans. G.S.S.A., Vol. 1928, pp.

to be of Bathonian age by W. KOERT.[24]) and definitely fixes the age of the Karroo beds as pre-Oolite. Fossiliferous marine Jurassic strata occur in Madagascar, while in the Mozambique Company's territory there are also deposits above the Karroo basalts which were probably laid down along the shore line of the same Jurassic sea. This, it may be noted, persisted throughout Cretaceous into Tertiary times, probably culminating in the Eocene, as evidenced by the wide extent of the Nummulitic Ocean and may have stretched right across the Indian Ocean, as well as over large parts of North East Africa, Arabia, Persia, India and Australia. Returning to our immediate subject, the beds seen eastward of the gneiss of the Usambara Mts., probably come in along a line of faulting or thrust. Exposures are rather poor, the strata being much obscured by laterite capped with sand, as for instance round Gombera and near Buriti. Hard fine-grained speckled sandstone (?belonging to the Taru grit series of Maufe) may be seen in places, together with shale, or the clay derived from its decomposition. Along the Msimbazi river, which was examined in some detail, the first rock noted east of the gneisses was striped shale dipping at 10 to 15° E. In this a contorted band was observed only two inches thick, shewing overfolds. Further East the beds as a whole were contorted and overfolded, no doubt in the neighbourhood of a fault or thrust. Felspathic grits are then seen, of a characteristic brownish colour. Indications of overfolds were noticed further downstream, and the dips were found to be very variable, in some places S.W., though more generally, especially lower downstream, S.E. It seemed clear that there must be overthrusts and the crumpling and minute puckerring of the rocks becomes so marked in places as to produce many pseudofossils. From the neighbourhood of a tributary called the Katjindu an apparently much less disturbed and almost consistently shaly series is passed over. In that stream itself hard shales are exposed with an E.S.E. dip of about 5°. Along the Msimbazi below it hard shales with occasional fragmentary plant remains dip very regularly at angles of less than 5° in an easterly or E.S.E. direction. The angle of dip is in fact only slightly greater than the fall of the stream. Near Jumbe Hassan's village above the main footpath, the shales shew hard concretionary nodules, nearly oval in plan as a rule, though they may be quite irregular. They are characterised by a peculiar criss-cross structure when weathered, and have very blunt ends, round which the softer laminae are squeezed, so as to produce a kind of eyed structure. A number of nearly complete skeletons of a lizard-like reptile were found about here, two being embedded in the ordinary shale and six in concretions. This reptile has been described by HAUGHTON as *Tangasaurus mennelli*, and is regarded as possibly indicative of a Beaufort age. What was taken to be an *Ullmannia*-like plant was rather common, and I made a special note of the fact that *Glossopteris* seems also to occur just above the

[24]) Zeit. Deutsch. Geol. Ges., Vol. lxi, 1904, p. 150.

reptilian horizon, as mentioned in a note appended to Mr. HAUGHTON'S description of the reptile. Proceeding north east from Jumbe Hassan's, the dark shale series continues for some distance; then near the Umkaka river, sandstones come on with much less fissile and lighter coloured shales than the lower series. These have a strong tendency to weather yellow. Where first seen the dips are very disturbed and steep, no doubt due to faulting. Near the Kombe river the shale contains septarian nodules with organic nuclei and crystalline calcite in the cracks. The strata in the river itself are fine sandstones and shales with a N.E. dip, this turn of the straka bringing on the Jurassic beds to the north. In the Kombe estuary at Vijinga there are fine sandstones with a reddish tinge dipping N.E. at about 5°. The Karroo beds here extend right up to the mangrove swamps into salt water, and no coral rock was seen near the main road. From the Kombe, Karroo strata continue for a few miles south, but soft well-bedded sediments that were taken to be either Jurassic or Tertiary are encountered some miles before reaching the Siji. The Jurassic limestone already mentioned as occurring on that river crosses the railway at 9 km. west of Tanga, and continues to Pongwe, gneiss being seen at 25 km., after some intervening soft sediments have been passed.

In connection with the middle or dark shale series of the simple classification suggested by TEALE, SEWARD considers that the plants, some of which have rather a European facies,[25]) point to a distinction in distribution, if not in age, from the normal Karroo. The absence of *Glossopteris,* however, on which much turns, does not, however, appear to be a fact, and that fossil has been recorded from a borehole penetrating the Taru grits in Kenya. Moreover the area which emerges from under the southern end of the same strip of Jurassic rocks as covers the one under discussion is entirely similar in lithological characters to this one, and the flora includes abundance of Glossopteris. Maufe also found Estheria (?greyi) in his Maji-ya-Chumvi beds, which seem to correspond with part of the uppermost subdivision adopted here, and this was regarded by R. B. NEWTON as of the same age as those from the Upper Matabola beds (Madumabisa shales) of Matabeleland, as well as those found by ANDREW and BAILEY [26]) in Nyasaland. HAUGHTON also considered *Tangasaurus* as probably of Beaufort age. It is not unlikely, therefore, that the dark shales correspond to the coal-bearing and associated beds of Rhodesia, while the underlying gritty series, including the Taru grits etc., may possibly be regarded as a much exaggerated representative of the Lower Wankie Sandstones.

Dr. TEALE regarded the strata here as of great thickness, upwards of 10,000 ft.[27]) Dr. PARSONS has recently suggested that extensive thrusting

[25]) Geol. Mag., 1922, p. 388.
[26]) Q.J.G.S., Vol. lxvi, 1910, p. 239.
[27]) Geol. Mag., 1922, p. 385.

occurs in the beds on the Kenya side of the border. While perhaps not indicating that the disturbances are of the importance attributed to them by PARSONS, it will be observed from what has already been said that the evidence appears to favour his views to a considerable extent.

Area East of Kisaki. This is a long strip about eighty miles in length from north to south. It emerges from beneath a covering of Jurassic beds which are the oldest sediments seen on the main line of railway, where they are faulted against the gneiss just east of Ngerengere station. As already mentioned, the Karroo beds here correspond closely in lithological character with those of the Tanga area on the other side of the younger rocks, 140 miles away, the same threefold division being observed. The basal beds are often red in colour and inclined to be conglomeratic, though they pass up into normal sandstones. Owing to faulting they are not as well exposed as in the Kidodi area to be referred to later. On the Kidete river the lowest beds seen were conglomerates and grits with some intercalated red mudstones: the junction with the gneiss is not improbably a fault, however, as crush breccia occurs in that rock where last seen. Carbonaceous shales appear higher up in beds not many feet thick, but conglomerate and grit like those lower down come in again above them. At the confluence of the Sumbadzi river with the Rufiji, there are massive sandstones, very like the Lower Wankie Sandstones, which have shale bands intercalated amongst them for some yards below the main mass of the overlying dark shales. They may be followed for about two miles downstream in the Rufiji, where they give rise to the Pangani rapids, disappearing under the dark shales just before those beds are themselves cut off by a fault. This runs in a N.W.-S.E. direction, but the throw is difficult to determine, as the nearest beds exposed on either side shew no signs of drag. On what is taken to be the upthrow side olive shales are seen which would thus appear to belong to the lower part of the Karroo system, and what may be the Pangani sandstone caps the hills to the south-west.

The dark shale series is well exposed along the Kidete, Mahumbi, and Sumbadzi rivers, especially the last, in which, owing to the numerous faults, the same beds are several times repeated. A very good section of the base of the shales is that about ½ m. above the confluence with the Rufiji. They there contain minute impersistent coaly seams, associated with many plant remains, *Glossopteris* being conspicuous, especially on a horizon about 1 to 2 ft. above the underlying sandstone. Upstream the chief features of interest are the faults and thrusts, and the sandstone "dykes." The last are extremely well exposed in a section a few miles above the confluence with the Rufiji, and are clearly connected with some very irregular and impersistent patches of sandstone occurring amongst the shales. The dykes are, as a rule, nearly vertical, and are very variable in width from point to point, ranging from less than an inch to over 2 ft. wide. They often ramify and contain in-

clusions of shale that no doubt dropped into them from above when they were open, as they doubtless were at the time when they were being filled with sand. The latter contains a considerable amount of felspar, including microcline and plagioclase, as well as plenty of rather large flakes of mica with biotite even more abundant than muscovite. Below the point where the dykes are exposed, there are two well marked faults, the direction of dip and drag being S.S.W., the dips being very steep in their neighbourhood. A little lower down the river there is a very good section shewing a very puzzling thrust producing an appearance of unconformity, with much folded beds below. Still further down there is a point where there are numerous fragmentary plant remains, one unmistakable complete frond of *Glossopteris* 3-4 ins. in length being seen. There are also some small coaly seams associated with impressions of stems of plants. Two more faults with a steep dip S.S.W. are again seen downstream, and further on the beds are again repeated by faulting before reaching the point where the shales finally disappear owing to the emergence of the Pangani sandstones from beneath them near the Rufiji. I was much struck by the very strong resemblance of the series to the Culm shales of the northern part of Devonshire, not only lithologically but structurally. Faulting and thrusting are even more prominent in this part of the Karroo system than near Tanga, and combined with the frequently steep dips again tend to substantiate the conclusions of Dr. PARSONS as to the importance of movements of compression among these rocks.

Proceeding north from the Rufiji towards Behobeho, no good sections were observed, though much coarse sandstone was seen lying about, as well as small pebbles weathered out of it. Shales are also observed occasionally, and like the other rocks are light coloured. Beyond Hatambulo (Mt. Johnston), there are yellowish weathering sandstones, coarse to fine, with small pebbles, and looking south from Behobeho, there is a well marked dipslope and escarpment like structure on a large scale, with the dips more or less west, but there is doubtless a good deal of faulting, as seen in the river sections. The lighter coloured beds may well belong to the uppermost division of the system. Leaving Behobeho, however, gneissic debris becomes conspicuous in the soil, and towards the Viranzi river exposures shew conglomerates like those seen along the Kidete, similar reddish mudstones being also well seen. They dip S. E. near the gneiss, which comes in at a stream between Viranzi and Matambo. Further north, after travelling over the gneisses from Kisaki, the first sediments struck near Genge were yellow weathering shales and sandstones, hence the boundary is probably a fault, as they no doubt represent the upper part of the formation. They continue across the Ruvu river towards the rapids on that river. I was informed that limestones (presumably Jurassic) come on to the east. The sandstones are apparently grey to white as a rule, where freshest, but are often ochreous when weathered. A rather coarse grit from a prospecting shaft, put down

near the Ruvu before the war, is seen in section to have such well rounded grains and such fresh felspar as to suggest aeolian conditions, but carbonaceous material occurs near by, and was indeed the cause of the work being done in search of coal. Some of the quartz grains shew secondary enlargements, in some cases with good crystal faces, the cementing material is, however, calcite. Going up the Ruvu the same strata are seen everywhere. The sandstones are sometimes pebbly and the shales have somewhat carbonacous seams in places, but there are no well defined plant remains. The sediments continue westward to Umvuha, but immediately beyond that village on the road to Tombozi crystalline limestone comes in, soon succeeded by gneiss, rising up from the sedimentary flats into hills, which culminate in the Uluguru Mountains, of which the highest point, Tambaku, is just about 10,000 ft. above sea level.

Kidcdi area. On the western side of the Uluguru Mts. there is a very hilly Karroo outlier, about 20 or 25 miles in length, and half that width, along the Ruhembe river and its tributary, the Deki. The latter was carefully examined, and the lowest beds were found to be largely reddish mudstones, occasionally interrupted by gritty beds of the same colour, and by grey sandstones. They are many hundreds of feet thick and are succeeded by the dark shale series. This latter appears to consist of a single highly carbonaceous division, probably a couple of hundred feet thick, with several hundred feet of alternating hard shales and fine grits overlying it, and a smaller thickness of similar strata beneath. The beds have a very consistent dip, westerly at first, and north-westerly lower down stream, but similar sequences are met with more than once. They are certainly cut by faults of some importance, in one case causing them to become vertical, or even slightly overturned and not to resume their normal dip of 20° or so for some hundreds of yards. At several other points exceptional dips like 45° are observed, which no doubt indicate faults, though there is no good section. There are a number of minor step faults, etc., noticeable in the carbonaceous shales, the coaly seam at their base being affected by several of them. This seam has quite a schisty appearance, and behaves like anthracite in a forge: its maximum thickness is about 2 ft. 6 in. Just above this seam some fairly well preserved impressions of fresh water shells were obtained in a pit. It it not clear whether the upper part of the formation is developed in this area. I was again struck here by the resemblance of the strata to the Devonshire culm, and there are even beds so like the radiolarian cherts that I had slices made, with however negative results.

Ujiji Area. The largest of the Karroo areas in the territory is that bordering on Lake Tanganyika which is intersected by the Malagarasi river. It is crossed by the Central line of railway, which has its terminus at Kigoma, a place that is practically a suburb of the well known Arab town

of Ujiji, the terminus of the old caravan route from the coast in the slave-trading days. The area is one that should repay extended study. Not only is it comparable in size with that of Matabeleland, but there are, as already mentioned, beds which may well be older as well as younger than the Karroo period. Passing along the shore of the lake going southward from Kigoma, thick lateritic gravels obscure the Karroo and other beds. They may be of Tertiary age, and appear to dip towards the lake, which is very deep near the shore at Kigoma, though quite shallow near Ujiji itself, a fact which has contributed much to the decay of that locality. Round Karago, south of the Malagarasi river mouth, brownish mudstones and sandstones are seen everywhere, with a somewhat variable, but probably general westerly dip. Limestone is also seen quite near the Malagarasi, of much the same colour as the mudstones, a small opening shewing it to be at least forty feet thick, the true base and top not being seen, though small seams of shale or mudstone occur in it. It contains a little chert, and is also oolitic in places where the beds were followed inland for two or three miles. Coming down a small stream towards the lake, an interesting series of step faults may be traced, by which the westerly dipping limestone is several times brought to the surface going in that direction. Although this faulting, like that of the Karroo beds on the north side of the Zambesi, tends to counteract the effects of the general dip, it does not altogether do so, and the beds may therefore overlie the amygdaloidal basalt of which there is a large area further inland, though I personally saw no trace of it save a small rolled fragment picked up near Karago. A slice of this proved it to be so altered that its appearance throws little light on the question as to whether it really represents the Stormberg basalts, except that it appears to be of basaltic character. None was observed in situ from the mouth of the Malagarasi to a point between the Rugufu river and Cape Kibogo, either along the shores of the lake or in the short distance inland that we penetrated in our traverses. It may be observed that if the beds already referred to, which are not very like anything in the Karroo elsewhere, except in N. Nyasaland, overlie the basalts, they must be regarded in conformity with usage further south as post-Karroo. Apart from the fact that they would be higher up in the stratigraphical sequence than anything in the type area, it will, I think be generally agreed that the Karroo system is quite extensive enough already, without making further additions to it in an upward direction.

South of Karago, the beds already referred to have the usual westerly dip, but after a time reddish sandstones come in with a northerly dip, so that there is apparently either a fault or an unconformity. Still going south the dips become very steep and finally about vertical, clearly indicating a fault with a dip about N.N.E., the downthrow therefore being rather away from the lake. A little further on, after a stretch with no exposures, the dip is quite steep to the south or south-west. Near the fishing station the

coast runs N.E. x S.W. and is very straight, the strike of the rocks being very nearly at right angles to it. They are grey and olive mudstones and shales. Fragments of coarse red pebbly grit are seen, but where they occur in situ, they have the appearance of being quite recent. Beyond the mouth of the Rugufu, the first exposures are of reddish weathering sandstones like those near Karago, with a dip of over 30° to the south-west, and therefore apparently indicating an anticlinal structure, arching over the much disturbed beds in between. To the south these beds become nearly horizontal, though steep dips are seen from time to time, probably in the neighbourhood of faults. For instance, at Kilandu, highly inclined pale but red-weathering sandstones dip under or are faulted against chocolate mudstones dipping at about 10° S.W. that have light coloured sandstone overlying them. The last dips south at a small angle, and becomes indeed nearly horizontal after a while. It then begins to steepen, and eventually reaches an angle of 45° to the south-west where last seen. These rocks are more like the Karroo beds of the south than any of the others met with, and may well belong to the upper part of the system. The older looking rocks north of the Rugufu may owe their appearance largely to the disturbances to which they have been subjected. Dr. Teale informs me he has traced the sediments into the neighbourhood of Lake Victoria, and is publishing a description of them, which will be awaited with much interest.

Further south there are two patches of Karroo rocks which the writer has not visited, and several others are known to the north of Lake Nyasa.[28]) There is also a large area east of that lake which appears to contain valuable seams of coal, and a small outlier near Songea, as well as one or two others in Portuguese Nyasaland, about which little is known. The character of the strata is no doubt to be inferred from that of the better known Nyasaland areas, which have been described by ANDREW and BAILEY, and more recently by DR. DIXEY.

Northern Nyasaland. There are several small sedimentary outliers west of Lake Nyasa near its north end, and though they are not of great size they shew a remarkable thickness of strata, which is a sure indication that they were formerly of very much greater extent. DR. DIXEY has in fact added 1,000 ft. to the thickness described around Mt. Waller by Messrs. ANDREW and BAILEY, making the total 4,000 ft., as follows:—

4.	Chiweta Beds: mudstones with thin conglomerates	1,000 ft.
3.	Mudstones, with thin sandstones and grits. (Upper Group of ANDREW and BAILEY)	1,500 ft.
2.	Sandstones, with shales and coal. (Middle Group of A. & B.)	200 ft.
1.	Sandstone, with basal conglomerate (Lower Group of A. & B.)	1,300 ft.

[28]) See W. BORNHARDT, Deutsch Ost Africa (Geol.) Vol. VII, 1900.

It will be observed that there is a considerable resemblance between the succession as given here and that described from the coastal regions of Tanganyika Territory. There are, as already mentioned, several other small areas further west, between 9° and 11° S. lat., particulars of which have been published by Messrs. ANDREW and BAILEY [29]) and supplemented by DR. DIXEY.[30]) It is only recently, however, that the wide gap existing between the N. Nyasaland areas and those of the Zambezi region has been bridged to some extent by the discovery of two small patches of Karroo strata just north of the 13th parallel, near the Dwanga river in Central Angoniland.[31]) The beds appear to belong to group 3 of the succession tabulated above. Neither at this point, nor at any other locality in Northern Nyasaland is there any sign of the Karroo basalts, which cover the sediments almost everywhere to the south. It may be remarked also that Messrs. ANDREW and BAILEY considered the strata in southern Nyasaland and the adjacent parts of Portuguese territory as of much greater thickness than to the north. In such a much faulted area such a conclusion is necessarily subject to modification as observations accumulate, and it appears probable from what is seen in Portuguese territory that the beds are not really so thick as they at first sight might appear to be, though they are still of much greater thickness than at Wankie and elsewhere in Rhodesia.

The fauna and flora of the Nyasaland deposits is similar to that of Rhodesia. In group 2 fronds of *Glossopteris* have been found, and they also occur in group 3, in the upper part of which *Palaeomutela* and *Estheriella*, as well as scales of a fish, first described as *Acrolepis*, and later as *Colobodus africanus*, have also been found. They do not lend themselves to any precise definition of the horizons at which they appear.

V. THE LOWER ZAMBEZI REGION.

This area, which comprises Portuguese Territory on both sides of the great river above the Lupata gorge, and on the north bank below it, as well as Southern Nyasaland, is a particularly large and interesting one, besides being the first that was brought to the notice of geologists. Information regarding it, is however curiously imperfect, apart from the Nyasaland section, which has been studied in some detail, both by ANDREW and BAILEY, and later by DR. DIXEY. The former authors recognised the same succession as in Northern Nyasaland, with the addition of the Karroo basalt (Q.J.G.S. 1910, p. 217) to which DR. DIXEY believes may be added a rhyolite horizon above the basalts which must be carefully distinguished from the later rhyolites of the Lupata Volcanic Series in the same area. (See G. Mag. 1920,

[29]) Q.J.G.S., Vol. lxvi, 1910, pp. 202-215.

[30]) Trans. G.S.S.A., Vol. xxix, 1926, pp. 59-68.

[31]) Loc. cit. p. 67.

p. 244.) As far as the Tete district is concerned, the writer was the first to point out the true position of the Karroo basalts in the eastern part of the area. (G. Mag. 1922, p. 169.) These had previously been overlooked, and the entirely different alkaline Lupata Volcanics first noticed long ago by LAPIERRE, confused with them, so much so that the name Lupata Volcanics has been applied to them by the various geologists working in the Tete coalfield, as may be seen in the most recent paper by B. KARPOFF (Bull. Soc. Belg. Geol., 1928.) They occur above the Lupata Gorge running north and south across the Zambezi. On the latter side they are separated by a short stretch of Lower Lupata sandstones from the strip which runs for such a long distance along the western border of the Mozambique Company's Territory, their southern termination being probably a continuation of the faults which runs N.W. x S.E. along the southern boundary of the sedimentary area on which the town of Tete is situated. To the north they appear to die out about 15 miles from the Zambezi, and they do not connect with the large area on the frontier between the Zambezi and Shire rivers.

SECTION IV.

THE GENESIS OF PETROLEUM.

30. DIE ENTSTEHUNG DES ERDÖLES, VERWANDTER KOHLENWASSERSTOFFE UND GEWISSER KOHLE.

VON

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(Berlin).

Bei dem geringen mir zur Verfügung stehendem Raum kann ich hier nur das Wesentlichste bringen; ich muss vor allem um Entschuldigung bitten, wenn ich nur ganz wenige Autoren dieses Riesenforschungsgebietes anführe. Ich komme an anderer Stelle ausführlicher auf das vorliegende Thema zurück.

I. ALLGEMEINES.

Erdöl kommt auf der Erde in der *verschiedensten Zusammensetzung* vor. Man gewinnt fast reines Benzin mit niedrigem Schmelzpunkt aus vereinzelten Bohrlöchern z.B. in den Vereinigten Staaten und in Hanover; wir finden in anderen Bohrlöchern dagegen zähflüssiges Machinen — und Schmieröl; häufig treten butter—und wachsähnliche Massen auf, die bis zum Asphalt hinüber leiten können, und schliesslich treffen wir in selteneren Fällen so gut wie reinen Kohlenstoff in Form von Kohle an—*Es finden sich also Uebergänge vom leichten Benzin bis zum fast reinen Kohlenstoff.*

Die *Form* des Auftretens der Kohlenwasserstoffe u.s.w. ist sehr verschieden. Wie das Grundwasser füllt das Öl die Poren und Spalten in den Gesteinen aus, Ölhorizonte bildend, anderseits kommt es aber auch als Ausfüllung von Blasenräumen und Spalten in Eruptivgesteinen vor.

Was die Entstehung anbelangt, so kennen wir ausserordentlich viele Methoden der Erdölherstellung und der Arten seines Auftretens. Viele Wege führen nach Rom!

ENGLER-HÖFER[1] haben in ihrem bekannten Erdölwerk eine Zusammenstellung gegeben, in den späteren Jahren hat R. POTONIE[2] sich mit der

(1) ENGLER-HÖFER: Das Erdöl.
C. ENGLER: zur Gueschihte der Bildung des Erdöls. Ber. d. Deutch. Chem. Ges. 33. F, 1900.

(2) R. POTONIE: Zuzammenstellung der Daten die für die organische Herkunft des Erdöls sprechen—Petroleum 1927, 13, No. 10.

Frage der Entstehung eingehend beschäftigt; HARBORT[3] veröffentlichte vor kurzem interessante Versuche im Laboratorium. Man hat sich im Laboratorium, seit es eine Petroleumgeologie gibt, beschäftigt, ohne zu einem endgiltigen Ergebniss zu kommen.

Vor allen Dingen begingen viele den Fehler der Verallgemeinerung, an dem ja unsere schöne geologische Wissenschaft so sehr leidet. Sobald ein Forscher durch einen interessanten Laboratoriumsversuch ein Ergebnis erzielt hat, glaubt er, dass seine Lösung die einzig richtige ist, und versucht durch Verallgemeinerung der Natur Zwang anzutun. Solange wir aber die Temperatur-und Druckverhältnisse in der Erdrinde nur bis zu den bis jezt bekannten geringen Tiefen kennen, haben wir kein Urteil über die in der Erdrinde von Art zu Art wechselnden Verhältnisse. Man vergleiche in dieser Beziehung Südafrika mit Deutschland: In Südafrika auf 212 Fuss Tiefe eine Temperaturzunahme um 1° F., bei uns auf dieselbe Tiefe rund 7° F. Bei solchen Unterschieden empfiehlt sich Vorsicht bei Verallgemeinerungen, da wir im Duncklen tappen.

Die künstliche Herstellung von Erdöl ist natürlich ein wichtiges Hilfsmittel zur Erforschung der Genesis und deshalb möglichst weiter auszubauen, man muss sich aber bei diesen Arbeiten immer wieder klar sein, dass man lediglich Einzelfälle unter gewissen Bedingungen untersucht, die keine Verallgemeinerung zulassen.

Die Geologie pflegte bisher bei der Entstehung des Petroleums eine anorganische von einer organischen zu unterscheiden. Die Bezeichnungen sind irreführend, da es sich in beiden Fällen ja um Kohlenwasserstoffe handelt, welche die Chemie zu den organischen Verbindung rechnet. Als anorganisch bezeichnet man bisher eine Genesis, die rein mineralisch ist und nichts mit Pflanzen oder Tieren zu tun hat.

Ich schlage deshalb vor, die bisherige Einteilung fallen zu lassen und künftig eine mineralische, Entstehung von einer solchen aus organischen Resten (Pflanzen und Tieren) zu unterscheiden.

II. BEISPIELE.

A. Mineralische Entstehung (ohne Mitwirkung von Tieren oder Pflanzen.)

(a) BERTHELOT[4] gibt an, dass sich durch Einwirkung von Kohlensäure auf Alkalimetalle Azetylsäuren bilden; duch weitere Einwirkung von Wasserdampf entsteht dann Azetylen=C_2H_2 d.i. ein Kohlenwassenstoff, aus dem sich Erdöl und Teerprodukte bilden können. Dieser Gedanke ist aber kaum übertragbar auf natürliches Erdöl, weil das Vorhandensein von

(3) E. HARBORT, Z.d. Deutsch. Geol. Ges.

(4) Compt. rendu—82, 949.

grösseren Mengen von freien Alkalimetallen in der Erdrinde nicht wahrscheinlich ist. Die *Möglichkeit* dieser Entstehung muss aber zugegeben werden.

(b) MENDELEJEFF[5] zeigt, dass bei der Einwirkung von Wasser auf Metallkarbide Metalloxyde und Kohlenwasserstoffe entstehen. Das Vorhandensein von grossen Mengen von Metallkarbiden im Erdinnern steht fest, ebenso, dass Wasser durch Risse in der Erdrinde eindringen kann. So ist also die Bildung von Kohlenwasserstoffen und damit von Erdöl auf rein mineralischem Wege gegeben. Auch HÖFER hält diese Theorie MENDELEJEFF'S für geologisch plausibel.

(c) Metallkarbide geben nach *Moissan* bei 0-150° mit Wasser Azetylen, Methan und Äthylen, ausserdem aber feste und flüssige Kohlenwasserstoffe und Harze. Dieser Vorgang ist in der Geschichte der Erde *höchst wahrscheinlich;* er dürfte in *allen geologischen Zeitaltern* festzustellen sein.

MOISSAN wiess übrigens schon darauf hin, das die Erdöle aus *sehr verschiedenen* Quellen stammen können.

B. *Entstehung aus organischen Resten von Tieren und Pflanzen.*

Die vielen bisher in der Literatur entwickelten Theorien sind alle möglich oder wahrscheinlich; ich weise auf die oben genannten Arbeiten von H. HÖFER, R. POTONIE, u.s.w. *Irrig ist aber die Ansicht vieler sich zu dieser Theorie bekennenden Autoren, dass das Petroleum ganz allgemein auf diese Weise entstanden sein soll.*

III. NATÜRLICHE BEIPIELE VON ERDOELVORKOMMEN.

Es ist eine bekannte Tatsache, dass sich Spuren von Kohlenwasserstoffen in vielen vulkanischen Gasen befinden. Eine der grössten derartigen Exhalationen ist diejenige auf Gran Canaria, die man gefasst hat und zu Heizzwecken benutzt.[7]

Mit Hilfe der Spektralanalyse wurden auch Kohlenwasserstoffe in den Kometen nachgewiesen.

Was Eruptivgesteine anbetrifft, so kennen wir Öltröpfchen in Effusiv- und Intrusivgesteinen. Sie finden sich im Basalt Mexikos[8]—vermutlich entstanden beim Durchbruch des Eruptivgesteins durch ölhaltige Schichten—im Basalt am Fusse des Ätna[9]—und im Werra-Kaligebiet, wo der Basalt

(5) Deutsche Uebersetzung v. H. Abich, Jahrb. geol. Reichsanst. Wien, 1879, 176.
(6) HOFER-HEIMHALT H. Das Erdöl und seine Verwandten—Braunschweig, 1922.
(7) L. FERNANDEZ NAVARROZ "Illes Canarres" Excursion A. 7. XIV Congrès géologique International, Madrid, 1926.
(8) L. BLUMER: die Erdöllagerstätten, Stuttgart, 1922.
(9) C. PORRO: In toma di recherche di petroles-Minera italiana V. No. 5—6, 1921.

die Kalisalze durchbricht,[10] im Dolerit Südafrikas in der mittleren Kapkolonie, wo ROGERS und DU TOIT[11] sie als Destillationsprodukt der Karookohlenschiefer auffassen, im Trachyt Nordungarns, im Dazit Kanadas u.s.w. u.s.w.

Der Melaphyr der Rheinpfalz und Böhmens ist bekannt durch Bitumen, welches als Blasenausfüllung auftritt. Derartige Vorkommen gibt es vielmehr.

Wir kennen weiter Bitumen im Granit van Clermont (Auvergne)[12] im nördlichen Schwarzwald-dunkelbraune Substanz von muschligem Bruch überzogen mit Eisenrahm und z.t. eingewachsen in Kalcit[13]—im Striegauer Granit (Schlesien)[14] zusammen mit Zeolithen und Kalkspat—in Schweden u.s.w.

In jedem Fall muss hier geprüft werden, ob das Bitumen aus kohlenwassenstoffhaltigen Exhalationen entstand oder beim Durchbruch des Eruptivgesteines aus kohlehaltigen Sedimenten herausdestilliert wurde.

Die Asphaltgänge in Fischfluss-sandstein im Süden von Südwest-Afrika mit Gesteinszerreibel, Kalkspat und Asphalt als jüngste Bildung sind, wie SCHNEIDERHÖHN [15] annimmt, aus aufsteigenden Kohlenwasserstoffen entstanden.

Die Petroleumgase im Becken von Münster [16] welche Spalten füllen wurden zuerst für Methan gehalten, aber später als von Erdöl herrührend erkannt.

In der Naebe tritt in Holland an der deutschen Grenze Erdöl in geringer Menge zusammen mit Kohle auf, derart, dass eine genetische Beziehung beider zu vermuten ist.

Hochinteressant ist das Steinkohlenvorkommen vom Dabrilugk rund 100 km. südlich von Berlin, ein neu entdektes Steinkohlenbecken, bei dem die Kohlenflöze von Keratophyen und Kersantiten durchbrochen werden und etwas Öl auftritt. Da die Steinkohle anthrazitisch und stellenweise sogar verkokt wurde, liegt es nahe, das Erdöl hier als Destillationsprodukt aus Eruptivgesteinen aufzufassen.

Das interessanteste Beispiel natürlicher Ölbindung wurde aber in Rüdersheim bei Berlin in einem stehenden Kanalstück vom Direktor P. KIER gefunden. Sticht man mit dem Stock in den Kanalboden, so steigen

(10) Nach C. DIETZ, Berlin.

(11) ROGERS n. DU TOIT: Introduction of the Geology of the Cape Colony. London. 1909.

(12) A. a. O. HÖFER, 1922.

(13) E. SCHRÖDER: Über ein Vorkommen von Drusenmineralien im einem Granit des nördlichen Schwarzwaldes-Centralbl. für Min. u.s.w., 1925, Abt. A. No. 9 S. 109.

(14) WEBSKY IN SCHWANDKE, Drusenmineralien im Striegauer Granit.

(15) SCHNEIDERHÖHN: Asphalt im Fischfluss-sandstein im Süden von Südwestafrika. Senkenbergiana Bd. I. No. 5, Frankfurt, a.M.

(16) P. KRUSCH: Zeitschr. d. Deutsch. Geol. Ges.

brennbare Blasen auf, und ein Ölhäutchen bildet sich an der Oberfläche. Ich liess durch R. Potonie den Bodenabsatz der Wassers untersuchen; er wies nach, dass er aus Faulschlamm besteht und das dieser Faulschlamm Öl-absondert.

Das ist der erste Anfang rezenter Petroleumbildung.

IV. Für die Beurteilung der Genesis des Erdöles ist auch die *Verflüssigung der Kohle* von Wichtigkeit, die heute in Deutschland eine grosse Rolle spielt. Bei der natürlichen Oxydation der Kohlenwasserstoffe wird diesen Wasserstoff entzogen und an Sauerstoff gebunden, sodass immer kohlenstoffreichere Verbindungen entstehen, bis schliesslich nur Kohlenstoff übrig bleibt. Bei der Verflüssigung der Kohle dagegen schlägt man den umgekehrten Weg ein. Man geht z. B. von der Steinkole aus und lagert an sie Wasserstoff an, bis sich wieder Kohlenwasserstoffe bilden. *Die Verflüssigung der Kohle ist also der künstliche, umgekehrte Vorgang, den die Natur bei der Oxydation der Kohlenwasserstoffe einschlägt.*

V. Wichtig für die Genesis ist weiter die *Verbindung der Erdölvorkommen mit Salzhorsten.* In den Vereinigten Staaten und in Hannover sind Saltz und Erdöl meist aufs engste vergesellschaftet, und zwar tritt das Öl häufig an den Flanken der Salzhorste auf. Dieses Zusammenvorkommen kann kein Zufall sein; es muss sich hier vielmehr um eine genetische Ursache handeln. Finden wir ja doch bei den Erdöl führenden Satteln an der Achse Gas, darunter Öl, und schliesslich noch tiefer an den Sattelflügeln Salzwasser; das Öl schwimmt gleichsam auf Salzwasser. Wenn nun auch diese Kombination in gewissen Distrikten feststeht, so darf man doch *nicht verallgemeinern* und den Schluss ziehen, dass alle Öllagerstätten auf diese Weise entstanden sind.

VI. Für die Entstehung des Öls sind die Begriffe *primäres* und *sekundäres* Öl von Wichtigkeit. Im allgemeinen sind die heute ausgebeuteten Öllagerstätten nach meiner Überzeugung sekundär d.h. das Öl ist durch die Erdwärme u.s.w. aus grosser Tiefe herausdestilliert und angereichert worden. Man begeht namentlich in Deutschland den Fehler, sich bei Tiefbohrungen aus Mangel an Geld mit den oberen Horizonten zu begnügen und nicht tiefgenug zu gehen. In den Vereinigten Staaten verfolgt man dagegen das wichtige Princip, die Bohrung möglichst tief zu treiben um sicher alle sekundären Horizonte festzzstellen, und womöglich den darunter liegenden primären zu finden; so erklären sich die Tiefbohrungen von rund 2500 m. im Westen Kaliforniens.

Es ist eine gekannte Tatsache, dass Ölbohrungen, die nur 30-50 m. von einander entfernt sind, auch bei horizontaler Lagerung aus gleichen Teufen, also aus demselben Öllager, ganz verschiedene Ölmengen liefern; so finden wir in Rumänien ausserordentlich hohe Produktionen, wie z.B. bis 1000 t. täglich, neben ganz geringen von wenigen Tonnen. Dieser Unterschied beruht nach meiner Ansicht auf der *Art der Zuführung* des Öls aus den tieferen Horizonten in die oberen. Sie kann durch Diffusion d.h. durch Wanderung in Porenzügen und auf feinsten Spalten oder auf mächtigeren Spalten vor sich gehen. Kommt nun eine Bohrung zufällig in eine Hauptzufuhrspalte eines Öllagers, so kann sie ausserordentliche Mengen liefern, während eine dicht daber stehende nur von dem ärmeren Oellager gespeiste, seht wenig ergibt.

Diese Zufuhrkanäle aus dem Mutteröllager und den tieferen sekundären nach den höheren sind also von grösster Wichtigkeit für die Entstehung der Erdöllager.

VII. *Die Kohle in den Witwatersrandkonglomeraten und ihr Anteil an der Genesis des Goldes*: Über sie und ihre Genesis ist schon viel veröffentlicht worden. Ich wurde von Herrn PERROT darauf aufwerksam gemacht, dass der Ingenieur MACADAM sich mit der Kohle in den Bankets beschäftigt. Auf meinen Wunsch sandte er mir ein reiches Material mit sehr genauen Angaben über die Art des Auftretens, und er drückte den Wunsch aus, dass womöglich mit Hilfe des Miethe'schen Röntgenverfanrens (Technische Hochschule zu Charlottenburg) untersucht werden möchte, ob es sich bei dem Banketkohlenstoff ev. um fossile Reste von Pflanzen u.s.w. handelt.

Der Kohlenstoff bildet in der Regel kleine Pünktchen von meist nur mm. Durchmesser, besonders häufig auf den Geröllen und im quarzigen Bindemittel, kommt aber auch in kleinen derben Massen vor und füllt ausserdem Spalten und dünne Gängchen aus.

Die Kohle hat eine rauhe Aussenseite und einen matt glänzenden Bruch und häufig ein kannalkohlenähnliches Aussehen, doch kommen auch anthrazitische Partien von bis ½ Zoll Durchmesser vor. Sie ist schwer brennbar.

Die mikroskopische Untersuchung ergab keinerlei Anhalt für eine Entstehung aus organischen Resten, es spricht vielmehr alles dafür, dass es sich um ein Oxydationsprodukt aus Kohlenwasserstoffen handelt wie ja auch YOUNG[17] vermutet.

Wie oben gesagt wurde, entsteht bei der Oxydation der Kohlenwasserstoffe schliesslich Kohlenstoff. YOUNG fand in der Kohle C34.2; SiO_2=20.1;

(17) R. B. YOUNG: The Banket, a study of the auriferous conglomerates of the Witwatersrand and the associated rocks, London, 1917.

$FeS_2 = 20.8$; Al_2O_3 (Silikat) $= 10.0$; und $H_2O = 11.9$. Sie ist also sehr unrein und hat wenig C; besonders auffallend sind die hohen Gehalte an FeS_2 und H_2O welche fossile Kohle nicht zu haben pflegen. Spuren van Co. As. Ti. und Au weisen auch auf mineralische Entstehung hin.

Die Kohle verdrängt Quarz, wie schon Young nachwies, und zeigt viele Klüfte, die Schrumpfüngssprünge sind. Sehr interessant ist die *Vergesellschaftung von Kohle mit Schwefelkies und mit gediegen Gold,* welche häufig mit blossem Auge beobachtet werden kann. Die nicht selten ringförmige Anlagerung beider Mineralien um die Kohle beweist, dass hier ein Reduktionsvorgang vorliegt; auf die sulfidischem und goldhaltigen Lösungen u.s.w. wirkte der Kohlenstoff durch Reduction ausfällend.

Kohlenwasserstoffaustritte sind in den Randgruben nichts seltenes, sogar Schlagwetterexplosionen von Wasserstoff kommen vor.

Alle Ergebnisse der Untersuchung sprechen also gegen fossile Kohle, es handelt sich vielmehr nach meiner Überzeugung um eine Ausfällung aus Gasen und Dämpfen, die auf Spalten aufstiegen.

Die Ansicht von Young über die Bildung von Kohlenstoff wird also bestätigt. *Die Kohle dürfte in enger Verbindung zu einem Eruptivgesteinsmagma stehen.* Diabas und andere basische Gänge durchsetzen häufiger die Konglomeratflöze und führen auch Kohlenstoff, namentlich in der Gegend von Rietfontein, Buffelsdorn und Randfontein.

Diese Entstehung des Kohlenstoffes der Witwatersrand-Conglomerate liefert einen wichtigen Beitrag zur *Genesis des Goldes.* Zweifellos ist der Kohlenstoff älter als ein Teil des Schwefelkieses und des gediegenen Goldes der heute vorliegenden Ablagerung; das wird die Umränderung des Kohlenstoffes durch beide Erze beweisen. Vermutlich folgten auf die in Verbindung mit basischen Eruptivgesteinen stehenden Kohlenwasserstoffexhalationen Minerallösungen, welche entweder Eisenulfid und Gold enthielten oder in der Lage waren, ältere derartige Erze umzulagern.

Wahrscheinlich steht die metasomatische Umwandlung von Konglomerratteilen in Kalkspat in enger Beziehung zu diesen Vorgängen.

Es wird eine meiner nächsten Aufgaben sein, an dem mir zur Verfügung stehenden Material zu prüfen, wie sich die Entstehung des Goldes im Witwatersrand-konglomerat unter Berücksichtigung aller Faktoren gestaltet und namentlich auch, welchen Anteil die Colloidchemie an der Ablagerung des Edelmetalles hat.

VIII. Ergebnis.

Es gibt unendlich viele Arten der Entstehung des Erdöls; es empfiehlt sich, zu unterscheiden,

(a) *Mineralische* und

(b) *aus organischen Resten entstandene Öle.*

Die bisherige Verallgemeinerung der Entstehung des Erdöls muss fallen gelassen werden, wie früher die „Kies" gruppe. Jede Lagerstätte ist vielmehr *individuell* zu behandeln und darauf hin zu untersuchen, ob aus mineralischen oder aus organischen Resten entstandenes Öl vorliegt.

Die Kohle der Witwatersrand-konglomerate ist nicht organischer Natur, sondern durch Kohlenwasserstoffe gebildet worden; sie bewirkte Reduktionskonzentrationen von FeS, und Au.

31. L'ORIGINE DEL PETROLIO.

PER

F. SACCO.
(Torino.)

E' noto che il Petrolio ed altri Idrocarburi possono avere un'origine organica (come mostrarono le esperienze di ENGLER, DAY, MC COY, ecc. derivando da speciali fermentazioni o decomposizioni di materie vegetali od animali), oppure un'origine inorganica (come indicarono le ricerche di BERTHELOT, DAUBRÉE, MOISSAN, ecc., per combinazioni o reazioni chimiche tra il vapor acqueo o fra Idruri, o l'Idrogeno stesso accluso nei magmi, ed i Carburi metallici accumulati nell'interno del Globo (1) o in altro modo.

Però gli studi geologici che da oltre un quarantennio vado proseguendo in varie regioni d'Italia, nonchè le ricerche varie fattevi da altri studiosi, mi hanno condotto a constatare:

A) che in Italia i terreni un pò petroliferi non sono già quelli più riccamente fossiliferi (come sarebbero per esempio varii calcari organogenici del Mesozoico e dell'Eocene, svariati depositi calcareo-arenacei, miocenici o pliocenici, zeppi di fossili, i giacimenti lignitiferì, ecc.), ma invece i terreni tipicamente noti per povertà di fossili, come sono appunto le cosidette "Argille scagliose" dell'Appennino.

B) che in Italia le zone più ricche in manifestazioni di Idrocarburi (gazosi, liquidi o solidi) sono più o meno strettamente collegate:

a) a formazioni di tipo plutonico, come sarebbero le *roccie ofiolitiche* (Serpentine, Diabasi, Eufotidi, ecc.) che affiorano a centinaia frammezzo dette "Argille scagliose," le quali sono anche spesso variamente colorate da ossidi di ferro, di manganese, ecc., oltre a presentare pure sovente svariate mineralizzazioni, quali Pirite, Calcopirite, Pirolusite, Magnetite, ecc. che accennano a correlazione con fenomeni endogeni (2).

b) a manifestazioni dell'attività vulcanica, cioè: sia certe *Sorgenti termali* (come per esempio quella caldissima di Abano, ultima manifes-

(1) Analogamente le Grafiti possono essere, sia di origine organica (come spesso quelle connesse a Schisti sedimentari), sia di origine inorganica, come quelle racchiuse in certi Graniti, in alcuni Ferri di origine magmatica, in qualche Meteorite, ecc.

(2) Ricordisi che il Tilden, il Gauthier, ecc. trovarono Idrocarburi nei Graniti, nei Gabbri, in alcune Ofiti e persino in Meteoriti.

tazione del Vulcanismo Euganeo); sia le cosìdette *Fontane ardenti* della Porretta e simili; sia i *Soffioni boraciferi* del Volterrano, (la cui costituzione chimica e l'alta temperatura sono di carattere spiccatamente endogeno); sia vere *roccie eruttive, basaltiche, filoni lavici,* ecc. come in varii punti della Sicilia; dove si trova persino petrolio in bollosità o geodi del Basalto, nelle lave doleritiche dell'Etna, ecc.; senza dimenticare che Grossmann e Brun estrassero Idrocarburi da varii prodotti Vulcanici (ossidiane, Lave e ceneri) del Vesuvio e dello Stromboli, e che Idrocarburi furono pure constatati in eruzioni vulcaniche.

c) ad importanti *Sorgenti termosolfuree*, a *formazioni solfifere* ed anche a veri giacimenti di *zolfo* (di cui è nota l'origine più o meno direttamente endogena), come in Romagna e specialmente in Sicilia, dove si trovano talora banchi asfaltiferi o bituminosi intercalati tra giacimenti solfiferi, talvolta impregnazioni ed emanazioni idrocarburiche connesse ad altre solfidriche e persino cristalli di zolfo rivestiti di bitume.

d) ad acque e formazioni *Saline,* cioè con più o meno abbondante *Cloruro di Sodio,* che può essere di origine sedimentaria, ma che spesso si mostra legato (per temperatura, posizione, ecc.) a fenomeni vulcanici; basti ricordare le calde Salinelle di Paternó presso l'Etna e l'abbondanza dei Cloruri sodici ed altri nelle eruzioni vulcaniche e nelle emanazioni annesse.

e) a *regioni tettonicamente molto disturbate* da forti corrugamenti, fratturazioni, faglie, nonchè da strutture diapiriche; fenomeni tutti che (costituendo soluzioni di continuita, quasi linee comunicazione attraverso la Litosfera), poterono permettere, anzi facilitare, la emigrazione delle emanazioni idrocarburiche salienti anche da grandi profondità (specialmente nei periodi diastrofici) ed il loro manifestarsi verso l'alto, sia some gas, sia come petroli; sia (per condensazioni, ossidazioni, ecc.) come impregnazioni bituminose, asfaltichè e simili. Tutto ciò variando secondo i tempi e le modalità di emigrazione e penetrazine, secondo la natura (più o meno porosa, calcarea od arenacea od altra) e lo stato (compatto o fratturato, ecc.) delle roccie attraversate. Come osservasi per esempio nelle zonule calcaree alternate colle "Argille scagliose" dell'Appennino emiliano, nei Calcari miocenici di Ragusa, nelle arenarie di Nicosia, ecc.

C) Quantunque le manifestazioni di Idrocarburi in Italia appaiano in diversi terreni, sia del Mesozoico superiore sia del Cenozoico, essi però mostrano talora di aver avuto un'origine più profonda.

Da tali dati di fatto constatati in Italia e che, del resto, presentano analogie anche con fatti consimili osservati in altre regioni della Terra, sembra logico dedurre che;

(1) Le formazioni petrolifere costituiscono generalmente depositi secondari, cioè roccie-serbatoio, piuttosco che non vere roccie-madri del Petrolio.

(2) Vi è un nesso genetico fra la maggior parte degli Idrocarburi (gazosi, liquidi o solidi) e le manifestazioni endogene (plutoniche, vulcaniche, solfatariche, ecc.)

(3) Per la maggior parte tali Idrocarburi, malgrado la loro posizione più o meno alta nella Crosta terrestre, sono di provenienza profonda.

(4) In conclusione essi hanno generalmente un'origine inorganica, sintetica, endogene o cosmica che dir si voglia.

ABSTRACT.

THE GENESIS OF PETROLEUM.

As experiences have proved, the genesis of Petroleum may be both organic and inorganic.

However geological studies in Italy show that in this country:

1. —........Petroliferous formations are not those which are the most rich in fossils, but those which are the less fossiliferous; such as the formation of "Argille scagliose" in the Appennin.

(2) —........The regions most rich in Hydrocarbons are in different ways connected:
   (a) with plutonic type formations; like the Ophioliths that appear amongst the "Argille scagliose" of the Apennines.
   (b) with manifestations of volcanic activity; such as eruptive basaltic stones and veins of lava; e.g. in Sicily.
   (c) with beds of Sulphur, whose origin is more or less directly endogene; as in Sicily.
   (d) with tectonically much troubled, fractured or diapyric regions; so as to allow the migration of hydrocarbon emanations, which, coming up from the depth, may form either gas, or petroleum or bituminous asphaltic impregnations, in accordance with the ages, state and nature of the formations traversed.

(3) —Although the manifestations of Hydrocarbons often appear in Cenozoic formations, they show a deep origin, even below Mesosoic.

After these geological facts observed in Italy it seems logical to deduce that a genetic connexion exists between Hydrocarbons and endogenic (plutonic, volcanic and sulphureous) manifestations; and that they have a deep endogene origin, which is therefore most probably inorganic.

32. ENTSTEHUNG VON ERDÖL AUS STEINKOHLE IN TIEF VERSENKTEN TEKTONISCHEN DRUCKGEBIETEN DER ERDRINDE.

VON

ERICH SEIDL.
Berlin-Westend.

(ABSTRACT).

Es ist erwiesen, dass sich aus thermischen Zersetzungsprodukten von Steinkohle unter dem Einfluss hoher Temperaturen und Drucke erdölhaltige Kohlenwasserstoffe bilden können. Hierauf beruht das Verfahren der " Kohle-Verflüssigung " von Bergius.

Gleichartige Bedingungen wie im Laboratorium und im technischen Betriebe sind auch im Erdinnern denkbar, wenn Steinkohlenlager—die zunächst sich an der Erdoberfläche gebildet haben durch geologische Vorgänge (Trogbildung) in grosse Tiefen und damit unter hohe Temperatur und hohen Belastungs-Druck gelangen. Es können ihnen dann durch Spalten, die in Verbindung mit dem Magma stehen, auch Stoffe zugeführt werden, die etwa für die Umsetzungen erforderlich sind (Metalle, Wasserstoffgas.)

Mir erscheint auch in geringeren Tiefen, in denen der Belastungs-Druck nicht ausreicht, die Entstehung hoher Drucke bei gewissen tektonischen Beanspruchungen der Steinkohlen-Schichten möglich.

So können bei der Einformung der Steinkohlen-Schichten in einen Trog. d.h. durch BIEGE—bzw. KNICK—Beanspruchungen an der konkaven Seite der Bogenbildung sehr hohe Druck-Spannungen entstehen.

Ich halte es daher für erforderlich, derartige Steinkohlen-Tröge, die in grösserer Tiefe auftreten, auf Erdöl-Bildung hin zu untersuchen.

33. IDEE SULLA PROVENIENZA DEGLI IDROCARBURI DI SICILIA.

PER

RAMIRO FABIANI.

La presenza d'idrocarburi è assai diffusa in Sicilia. Si tratta di gas infiammabili, die petroli, di bitumi e d'asfalti. Fino ad ora una vera importanza economica offrono però soltanto le formazioni asfaltifere, le quali assumono sviluppo notevole a Ragusa, presso Scicli e più a Nord a Vizzini e Licodia Eubea, sempre nella Sicilia orientale e in vicinanza o anche a contatto delle masse basaltiche e dei depositi piroclastici dei Monti Iblei. L'impregnazione bituminosa del Ragusano interessa essenzialmente i calcari del Miocene (Langhiano), però si riscontrano bitumi e petroli anche entro i tufi vulcanici e nelle fessure o nei vacuoli delle lave basaltiche.

Anche nelle lave dell'Etna fu trovata qualche inclusione di petrolio. Abbondante è pure il bitume entro i basalti di una località (Cozzo Grillo) di Pachino presso il Capo Passero.

Com'ebbi ad esporre con un certo dettaglio in altra occasione (¹), la presenza di manifestazioni d'idrocarburi in Sicilia si nota inoltre generalmente dove esistono soluzioni di continuità o anomalie di contatto nelle formazioni in dipendenza da filoni e dicchi di rocce eruttive o da fenomeni tettonici (fratture, faglie, pieghe-faglie, faglie inverse con ricoprimento, giaciture diapiriche.)

Aggiungasi che gli indizi d'idrocarburi, se sono più frequenti in corrispondenza a certi livelli geologici, si riscontrano però un pò ovunque nella serie stratificata. E qui va notato che il complesso delle formazioni geologische che costituiscono la Sicilia nelle regioni ove trovansi tracce d'idrocarburi, ha pe base una potente massa, in prevalenza argillosa, riferibile alla parte bassa del Trias superiore, il cui substrato ci è finora ignoto. Infatti di rocce più antiche si conoscono solo le rupi calcaree per-

(¹) FABIANI, R.—*Geologia degli idrocarburi della Sicilia anche in rapporto colla formazione degli zolfi.* Boll. Ass. Min. Sic., no. III. Palermo, 1927.

miane della valle del Sosio, le quali risultano generalmente senza radici e circondate dai sedimenti del Trias ([1]).

A quanto ho potuto finora assodare non vennero trovate tracce d'idrocarburi entro rocce del Trias, mentre sono invece discretamente diffuse entro quelle del Giurese. Alcune di quelle che ho potuto accertare nel Giurese, sono però generalmente in corrispondenza a disturbi tettonici che interessano anche il Trias.

Più frequenti sono le manifestazioni gassose, liquide e solide (bitumi, asfalti) nelle formazioni terziarie, però, da tutti gli elementi raccolti in quattro anni di ricerche in varie parti della Sicilia, ho tratto la convinzione che nessun deposito appartenente a tali formazioni sia per questo da considerarsi come roccia madre degli idrocarburi siciliani. E neppure sono del parere che le formazioni terziarie siciliane possano a qualche loro livello presentare delle rocce-serbatoio di rilevante entità.

Per le circostanze accennate e per altre che ho specificate in altra pubblicazione ([2]) o che ho avuto modo di rilevare successivamente, io sono d'avviso che gli idrocarburi della Sicilia siano di provenienza profonda (con ogni probabilità forse inorganica), in generale più profonda delle formazioni argillose che formano la base finora nota della serie triasica siciliana. Le soluzioni di continuità nella massa stratificata, per fratture, faglie, pieghe-faglie, fenomeni di diapirismo, intrusioni vulcaniche, furono la causa occasionale e nello stesso tempo la via dell'emigrazione degli idrocarburi, emigrazione che in certe aree (Iblei) appare concomitante all'acme eruttivo e che dev'essersi manifestata con maggiore intensità durante il Pliocene. Il fenomeno sembrerebbe però avvenuto a riprese, presumibilmente non contemporanee per tutte le parti dell'Isola.

Dal lato della ricerca pratica degli idrocarburi liquidi, è mia opinione, ripetutamente esposta, che le indagini debbano essere praticate con sondaggi profondi da piantarsi in punti tettonicamente adatti di quella parte del Trias affiorante in Sicilia che sta alla base della serie e che deve per la sua natura in prevalenza argillosa aver costituito una coltre impermeabile alla locale migrazione degli idrocarburi.

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(1) Fabiani, R.—*A proposito d'une ricerca del Carbonifero in Sicilia*—Boll. Ass. Min. Sic. Ann. V, No. 4. Aprile 1929. Palermo, 1929.

(2) Fabiani, R.—*Geologia degli idrocarburi della Sicilia anche in rapporto colla formazione degli zolfi.* l.c.

ABSTRACT.

Ideas regarding the origin of hydrocarbons of Sicily.

Evidence of Hydrocarbons is widely spread over Sicily (natural gas, petroleum, bitumen, asphalt). However, only the asphalts of Ragusa have, for the present, an economical interest.

Bitumen and traces of petroleum may also be found in the volcanic rocks and tuffs. Evidence of Hydrocarbons is localized in highly perturbed tectonic areas and particularly in faults. These tectonic disturbances affect not only the Tertiary but also the Secondary up to the known basis of the Trias (basal part of the upper Trias).

The rich evidence gathered by the author in all parts of Sicily confirms a *deep* origin of the Sicilian hydrocarbons viz. from under the lower part of the known Trias.

Therefore the author believes that the petroleum in Sicily must be searched by means of deep wells driven through the Trias, the basis of which is formed by a mass of impermeable rocks.

The migration of the hydrocarbons from the depths, it is believed, took place specially during the Pliocene time.

SECTION V.

THE GEOLOGICAL WORK OF MICROORGANISMS.

34. SULL'ORIGINE BIOLOGICA DEI DEPOSITI DI FERRO E DI SOLFO.

PER

DR. GINO BARGAGLI-PETRUCCI.
(Firenze-Italia.)

La scoperta, fatta da Ehremberg, di microorganisimi filamentosi capaci di rivestirsi di un involucro ocraceo di idrossido di ferro, e la constatazione della presenza di simili involucri in alcune ocre di origine sedimentare, recente od anche antica, aveva già fatto ritenere ad alcuni che quei microorganisimi potessero considerarsi come la causa specifica di simili depositi di idrossido di ferro. — Però, dato che in molti altri depositi ocracei, di origine pure sedimentare, non si riusciva a constatare nessuna traccia delle guaine ferruginose di cui quei microorganismi si rivestono, aveva assai diminuito il valore dell'ipotesi di una origine biologica per tali sedimenti (Molisch.)

Nè valsero a togliere il dubbio ai geologi le giuste osservazioni di Gasperin relative alla facilità con la quale possono scomparire da un deposito ocraceo le traccie dei microorganismi, quando il deposito stesso si trova esposto a determinate vicende, specialmente ad alternative di disseccamento e di immersione, in seguito alle quali ogni aspetto organoide può scomparire, lasciando che il deposito assuma completamente apparenza di semplice deposito idrico.

Vinassa De Regny ritenne che le spiegazioni chimico-meccaniche avanzate per spiegare l'origine delle "terre rosse" fossero inaccettabili; ma d'altra parte considerò insufficienti le ipotesi biochimiche, ed espressse la convinzione che fosse erroneo attribuire ad una sola causa l'origine di tutte le terre rosse. Inoltre egli ammise che il ferro si trovi nell'acqua "non allo stato di sale solubile, ma allo stato di sale sospeso, in soluzione colloidale."

Questo modo di vedere, in apparenza favorevole ad una ipotesi fisico-chimica sull'origine delle terre rosse, concorda invece in modo notevole con una ipotesi biologica. — Lo stesso Autore infatti notò come, se si fanno pervenire soluzioni colloidali di ferro in contatto con acque contenenti, in sospensione, materiale argilloso, questo materiale provoca la precipitazione dell'idrossido di ferro, e si verifica così la deposizione di un sedimento argilloso-ocraceo.

Ora questo fenomeno avviene anche se si parte da una soluzione di un sale di ferro (citrato, tartarato, bicarbonato), perchè si osserva allora che il sale di ferro dà prima origine ad una soluzione colloidale di idrossido di ferro, ed in un secondo tempo si verifica la deposizione argilloso-ocracea osservata dal Vinassa.

Se la seconda fase del fenomeno può ascriversi a cause puramente fisciso-chimiche, più difficile sarebbe attribuire ad esse la prima fase, la formazione della soluzione colloidale di idrossido di ferro.

Al VII° Congresso della Società Italiana per il Progresso della Scienze (Siena 1913) furono presentati i reultati di una serie di esperienze, dalle quali resultavano i fenomeni sopra accennati, ma resultava inoltre che tali processi non avevano più luogo se tutto il materiale posto in opera (*sopra tutto il materiale argilloso*) veniva in precedenza sottoposto ad accurata sterilizzazione, o se si aggiungevano al materiale in esperienza sostanze antisettiche o almeno avverse allo sviluppo di microorganismi. (Bargagli-Petrucci Gino: "L'origine biologica della *terra di Siena*" in Atti della Società Italiana per il Progresso delle Scienze Settima Riunione, Siena 1913.)

Contemporaneamente, nel Nuovo Giornale Botanico Italiano (Firenze 1913) venne descritto minutamente un microorganismo, *non appartenente* al gruppo dei microorganismi capaci di rivestire il loro corpo di un involucro ferruginoso ma pure attivissimo nella elaborazione del ferro in soluzione, perfettamente coltivabile, tanto in soluzioni liquide quanto in substrati a base di agar, che nelle culture si dimostrò capace di trasformare le soluzioni di un sale ferroso (citrato, tartarato ecc.) in soluzioni colloidali di idrossido di ferro che si depositava poi lentamente al fondo delle culture liquide,.e che veniva a formare, nelle culture in agar, granulazioni ferruginose in tutto simili a particelle di depositi ocracei non derivanti da Chlamydobacteriacee (*Crenothryx*, ecc.)

Questo microorganismo (*Bacillus ferrigenus*) era stato isolato dai terreni, dai fanghi e dalle acque della zona boracifera toscana (Larderello) a temperature assai elevate, in presenza di rilevanti quantità acido borico, e generalmente in substrati nei quali vivevano specie diverse di alghe monocellulari a formare talvolta non lievi strati verdi, ricoperti poi di incrostazioni ferruginose ricche anche di acido borico.

Da tutte queste osservazioni derivava naturalmente l'ipotesi che un minerale ferruginoso, caratteristico appunto della zona boracifera, la Lagonite, potesse aver origine biologica; ed in una breve memoria dedicata a questo argomento (Bargagli Petrucci: "L'origine biologica della *Lagonite*" in Nuovo Giornale Botanico Italiano, Firenze 1913) furono riassunti i fatti principali in appoggio di tale modo di vedere, che cioè la "lagonite" si fosse formata sotto l'azione di microorganismi simili al *B. ferrigenus*. In figure annesse alla nota furono messe a confronto piccole particelle di *lagonite* (a piccolo ingrandimento) con particelle di deposito ferruginoso

formatosi, sotto l'azione del B. ferrigenus, sopra un substrato artificiale, in presenza di alghe.

Quei fenomeni che si potevano ottenere artificialmente in culture, pure o impure; fenomeni che probabilmente hanno data origine alla formazione della lagonite, poteva supporsi si fossero verificati in altre epoche ed in altre località, e l'argomento meritava un più accurato esame.

Un magnifico esempio di depositi ferruginosi sedimentarii sono le così dette "terre di Siena" o "terre gialle e bolari" che si riscontrano (e vengono industrialmente utilizzate) nel Monte Amiata (Prov. di Siena.) — Come questi depositi, accuratamente esaminati con la scorta dell'ipotesi microbiologica sulla loro origine, prestassero all'ipotesi stessa indirette conferme, con il loro aspetto, con la loro distribuzione, con la loro struttura e con i reperti biologici e microscopici fu descritto in una memoria pubblicata dalla Reale Accademia dei Lincei (Anno CCCXI 1914) dal titolo: "Sull' origine biologica della *terra di Siena*," nella quale veniva affermato, che probabilmente "il processo biologico di ossidazione del ferro è ancora in azione in certi terreni, ed è molto più diffuso di quanto si potesse pensare" e si aggiungeva che "esiste probabilmente nei terreni argillosi una flora batterica che potrebbe meritare il nome di *geloide* e che meriterebbe tutta l'attenzione degli studiosi, specialmente allo scopo di determinare quale è l'azione che essa esplica sul suolo stesso e sulle piante superiori ad esso proprie."

D'altra parte fu possibile mettere in chiaro un'altra importantissima azione del *B. ferrigenus* sopra l'ambiente circostante, la formazione cioè di una sensibile quantità di *ozono* durante l'ossidazione biologica del ferro, per effetto dello sviluppo del microorganismo suddetto (Bargagli-Petrucci: *Il Bacillus ferrigenus come produttore di ozono* in Nuovo Giornale Botanico Italiano 1915), e questo fenomeno poteva mettersi in relazione con la presenza di ozono in alcune di sorgenti dello stesso Monte Amiata; presenza già constatata dall'illustre chimico Prof. Sen. R. Nasini. — La ricerca in tali acque di microorganismi che godessero proprietà analoghe a quelle del B. ferrigenus, nei riguardi dell'ossidazione del ferro e della formazione di ozono che l'accompagna, dettero resultato favorevole, confermando l'ipotesi che fra l'ossidazione del ferro (con consequente deposito di materiale ferruginoso), la produzione di ozono, e la vita dei microorganismi, esistesse un rapporto diretto e strettissimo, tale da autorizzare l'affermazione che i primi due fenomeni fossero appunto determinati da quei microorganismi.

Infine, partendo dal dato di fatto che il *B. ferrigenus* prosperava in un ambiente ricco di idrogeno solforato e di solfuri, quale è quello boracifero di Larderello, fu studiata l'azione del microorganismo su questi compositi ed il resultato degli studii fu che la presenza, nelle culture, dei microorganismi, indirizzava la trasformazione di quei composti in una direzione diversa da quella che essi seguono per effetto della normale ossidazione chimica.

Mentre infatti nelle prove sterili si aveva l'ossidazione diretta dei solfuri in solfiti e poi in solfati; nell'ossidazione biologica si aveva per effetto dell'azione ossidante del *B. ferrigenus*, in primo luogo *solfo* che conferiva al liquido una rilevante opalescenza; questo, si combinerebbe poi con solfito sodico originato da ossidazione spontanea del solfuro, e si otterrebbe allora formazione di iposolfito. — Qualora questa seconda fase della reazione venisse a mancare, lo zolfo, originato da ossidazione biologica, verrebbe a depositarsi al fondo. (Bargagli Petrucci C. Mayer, M. "L'ossidazione biologica dell'idrogeno solforato" in Nuovo Giornale Botanico Italiano 1914.)

Era naturale che un tale resultato sperimentale inducesse a concludere che verosimilmente anche nella deposizione dello zolfo in natura potessero avere notevolmente influito microorganismi ossidanti. — E l'esame dei fatti relativi ai depositi gessoso — solfiferi della Sicilia apparve così concordante con tale supposizione, da autorizzare una vera e propria " Ipotesi biologica sulla deposizione dello zolfo durante l'epoca gessoso-solfifera" (Bargagli Petrucci in Rendiconti della R. Accademia dei Lincei (nota I e nota 11°, 1915.)

Secondo tale ipotesi la deposizione dello zolfo sarebbe avvenuta sotto l'influsso che microorganismi ossidanti avrebbero impresso alla ossidazione dei solfuri in via biologica: la formazione del gesso sarebbe inveve il resultato di una ossidazione puramente diretta da azioni chimiche, al cessare, od al sospendersi della vita microbica. — Nè l'aspetto dei depositi solfiferi apparve in contrasto con tale ipotesi. In essi, e nelle loro stratificazioni si leggerebbero le alternative di attività, maggiore o minore, della vita microbica, la sua sospensione, ecc., ecc.

Ed è notevole il fatto che, tanto nel caso dei depositi ferruginosi del Monte Amiata, quanto nel caso dei depositi di zolfo della Sicilia, della Romagna e della Toscana, i depositi minerali sono stati accompagnati da vegetazioni algose, che ci vengono rivelate dalla presenza dei gusci silicei delle Diatomee, che si riscontrano in strati sottostani, sovrastanti e talvolta alternanti, con gli strati del minerale. — È, in fondo, lo stesso fenomeno che si verifica tuttora nella zona boracifera toscana, dove le incrostazioni borico-ferruginose e borico-solfifere sono quasi sempre sovrastanti a strati algosi che sono un ottimo substrato di sviluppo per il *Bacillus ferrigenus*.

Tutti questi fenomeni che hanno, mi sembra, una notevole importanza geologica, oltrechè biologica, sono spiegati, non con ipotesi prive di ogni base sperimentale; ma con ipotesi invece nate proprio da resultati concreti di ricerche sperimentali, e ciò spero possa conferir loro un maggior grado di attendibilità.

Del resto, più recentemente, (1919), E. C. Harder potè constatare il fatto (già descritto per il B. ferrigenus fino dal 1913) della trasformazione in idrossido di ferro *colloidale* del ferro contenuto in soluzioni di citrato ferro-ammoniacale, in presenza di microorganismi indeterminati, ed ai

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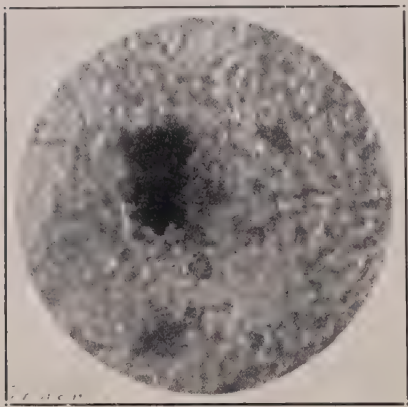
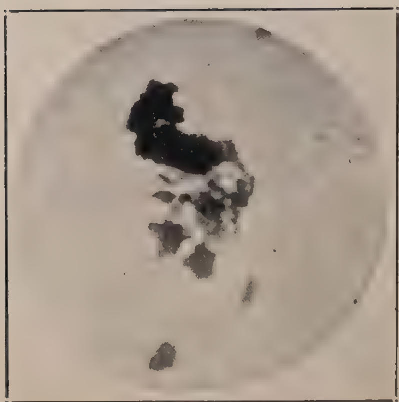


Communication No. 34

A. Concrezione di idrossido di ferro di origine biologica. (substrato algoso).



Communication No. 34.

B. Frammento di "Lagonite."

microorganismi attribuì egli pure la causa del fenomeno, dato che la sterilizzazione impediva il verificarsi di esso.

HARDER però dichiara di non aver potuto mai rintracciare microorganismi nella massa del ferro colloidale prodottasi, ciò che ha dato occasione a Molisch di prospettare l'ipotesi (che però a lui stesso sembra poco probabile) che il fenomeno possa essere dovuto a microo.ganismi ultramicroscopici.

Io penso che il mancato ritrovamento di microorganismi da parte di Harder possa essere dovuto a qualche difficolta di tecnica microscopica she occorre superare quando si ha presenza di idrossido di ferro colloidale, a meno che HARDER non abbia limitate le sue ricerche ai cosi detti clamidobatteri ferruginosi (Chrenothrix e simili.)

Molisch, ripetendo le esperienze di HARDER, le conferma pienamente (Molisch — Pflanzenbiologie in Japan — Jena 1926) e presenta (pag. 54) una figura di culture batteriche con deposizione di idrossido colloidale di ferro; confermando cosi (certo senza averne avuta cognizione) i fenomeni gia descritti a proposito del *B. ferrigenus* nel 1913 e rappresentati in modo, a parer mio, più evidente, nella tavola XI annessa al Vol. XX nel Nuovo Giornale Botanico Italiano.

La conclusione alla quale Molisch giunge, che microorganismi capaci di precipitare il ferro dalla soluzioni dei suoi sali siano assai diffusi in Natura, e che essi abbiano grande importanza nella circolazione del ferro è pienamente concorde con quanto lo studio del *Bacillus ferrigenus* aveva già fatto prevedere, e con quanto già era stato a suo tempo esposto nell' avanzare le ipotesi sopra ricordate circa una probabile origine biologica di minerali importantissimi quali la *lagonite, le terre gialle, bolari* e *rosse*..

Io credo anzi che si possa e si debba concludere che non solosui depositi di minerali di ferro, ma anche su molti altri depositi sedimentarii abbiano avuta influenza preponderante i microorganismi, come lo dimostrano le esperienze sull'ossidazione biologica dell'idrogeno solforato e dei solfuri e la conseguente ipotesi sull'origine biologica dei depositi solfiferi.

L'importanza che deve avere avuta e deve avere tuttora la Vita come fattore geologico dovrà essere sempre più ammessa e maggiormente studiata, sulle traccie di un illustre geologo italiano, lo Stoppani, che, pur non potendo avere al suo tempo le idee precise che oggi noi abbiamo sulla biologia degli esseri piccolissimi, pure aveva intuita tutta l'importanza che la Vita doveva avere nei più grandiosi tra i fenomeni di economia naturale.

FIG. A.
Concrezione di idrossido
di ferro di origine biologica.
(substrato algoso)

FIG. B.
Frammento di "Lagonite."

ABSTRACT.

Sur l'origine bio-chimique des dépôts de fer et de soufre.

La connaissance de microrganismes capables de s'entourer d'une enveloppe ferrugineuse (*Galonelle, Crenothrix,* etc.) conduisit à l'hypothèse que les dépôts sédimentaires d'hydroxide de fer (ocre, limonite, terres rouges, jaunes, bolaires etc.) ont pu se former par l'action de ces micorganismes filamentaux, même des eaux contenantes très peu de fer.—Mais les traces de ces microrganismes furent rarement constatées.

D'allieurs pour attribuer l'origine de ces dépôts a des causes physico-chimiques, il fallait admettre que partout où ces dépôts existent, des sources ferrugineuses existaient (qui ont disparu ensuite) même dans des endroits où il était bien difficile les admettre.

La question est simplifiée par la constatation de l'existence d'autres microrganismes qui, tout en ne se révêtissant pas d'involucres ferrugineux, agissent sur les eaux contenantes de petites quantités de sels de fer, en les transformant en hydroxyde de fer *colloidal* qui se dépose lentement au fond du liquide. Cette constatation résout les doutes principaux opposés a l'hypothèse biochimique.—Le *Bacillus ferrigenus* que j'ai isolé des dépôts ferrugineux de la région boracifère toscane, est le type de ces microrganismes.—Dés le 1913 je pus le cultiver en cultures où les dépôts d'hydroxide de fer se produisirent regulièrement.

De nouvelles recherches demontrèrent que de pareilles actions sont très diffuses dans la Nature, surtout dans les terrains argileux où la formation de dépôts argileux ferrugineux est fréquente.—De ces constatations dériva l'hypothese, fondée sur des données biologiques expérimentales, que l'ont dû attribuer à de pareils microrganismes l'origine de la *"terre de Sienne,"* ainsi que du caractéristique mineral *"lagonite"* de la région boracifère toscane, et aussi de bien d'autres dépôts ferrugineux dans lesquels on n'a pas pu constater la présence d'involucres de Chlamydobacteriacées.

En même temps l'étude de l'action du *Bacillus ferrigenus* sur l'hydrogène sulfuré et sur les sulfures conduisit à l'hypothése que telle action ait determiné la formation des dépôts de soufre, tandis que l'oxydation de l'hydrogène sulfuré et des sulfures, par action purement chimique, conduit au contraire à la formation de sulfates (ex. sulfate de calcium).

L'énergique action oxydante de ces microrganismes est accompagnée, du moins dans le cas de l'oxydation de sels de fer, par la formation *d'ozone,* et cela explique la présence de ce gas dans les eaux qui surgissent près des dépôts ferrugineux encore en activite, et desquelles ces microrganismes ont été effectivement isolés.

Les recherches plus récentes de Harder et de Molisch ont confirmé mes precédentes recherches.

35. SULLA NATURA E GENESI BIOGENICA DELLA PELAGOSITE.

PER

E. ONORATO.

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La Pelagosite delle Isole Tremiti, da me descritta in un recente lavoro(xx) analogamente a quella di altre località si presenta come unincrostazione nerastra, porcellanacea e costituita per lo più da piccole sporgenze mammellonari, a guisa di goccie. In lamine sottili essa è trasparente e colorata leggermente in giallognolo, con struttura fibroso-raggiata a strati sovrapposti, compredente però soltanto una zona esterna della goccia. Gli studi precedentemente fatti su questa formazione (carbonato dicalcio impuro per sali inorganici e residui organici) portarono ad interpretazioni differenti sulla sua natura mineralogica. Dopo che il Marchesetti (1) ne misurò la durezza (dr=4) superiore a quella della calcite, restarono per essa le due sole possibilità: *aragonite e varietà di calcite*. Il comportamento alla reazione cromatica di Meigen sembrava confermasse (2) la prima, ciò non per tanto essa appariva meno verosimile (3e4) sia perchè era stato osservato (5) che la presenza di aragonite, anche in piccole percentuali, può mascherare il colore della calcite o di una sua varietà più stabile dell'aragonite stessa, sia perchè sarebbe stato constatato (4) il carattere monoassico delle fibre. Per risolvere questa prima incertezza ripresi il saggio della reazione cromatica, seguendo però il metodo di Thugutt; i granuli, preventivamente lavati col solfuro di carbonio e con acetone, diedero evidente la reazione caratteristica dell'aragonite. Determinai l'indice di rifrazione nella direzione di allungamento delle fibre, ed ottenni per esso 1,529 cioè approssimato a -0,001 con n_a dell'aragonite. Questi due risultati ed il valore di altre due costanti fisiche: durezza=4 peso specifico=2,815, non lasciavano dubbio sull'identificazione della pelagosite con l'aragonite,

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xx) Sulla Pelagosite delle isole Tremiti nell'Adriatico Soc Geol Ital Vol XLV (1926) p. 17. Riassunto dell'A; con breve aggiunta.

anche perchè mi risultò inesistente il carattere monoassico delle fibre. Dall'analisi chimica ottenni i seguenti risultati:

$Ca\,O$	45,84
$Mg\,O$	1,50
$Sr\,O$	1,59
$Al_2\,O_3$	0,57
$Fe_2\,O_3$	0.32
$K\,Cl$	1,63
$Na\,Cl$	3,66
CO_2	37,56
SO_3	2,32
$Si\,O_2$ ins.	0,15
$Si\,O_2$ sol.	0,32
H_2O (a 120°)	2,44
Sost. org. (=p.d.)	2,10
Totale=	100,00

La ricerca dello stronzio tra le impurezze, non fatta nelle analisi precedenti, mi fù consigliata dalla natura mineralogica delle fibre.

Tra i sali che inquinano il carbonato di calcio ho potuto direttamente riconoscere: la dolomite e l'anidrite. Essendomi formato la convinzione che il residuo organico, costantemente presente in questa formazione, non potesse essere casuale, provai, con ripetuti tentativi, a separarli nelle migliori condizioni dal carbonato di calcio, adoperando una soluzione diluita di acido acetico. Per il cortese intervento della dott. Bambacioni, furono riconosciute due alghe azzurre (Schyzophyceae), appartenenti l'una alla famiglia Chroococcaceae gen. *Chroococcus* e l'altra alla famiglia Scytonemataceae, gen. *Scytonema*. Se controversa era la natura mineralogica della pelagosite, altrettanto era anche la sua origine e le differenti ipotesi avanzate uossono così riassumersi:

1) Metamorfosi di sostanze organiche (6). 2) Vetrificazione delle roccie calcaree (7.) 3) Reazione chimica tral'acqua del mare e le roccie calcaree o dolomitiche (8 e 9.) 4) Precipitazione del carbonato di calcio contenuto nell'acqua del mare per liberazione di CO_2: a) secondo alcuni (10) il deposito si sarebbe ottenuto durante le tempeste, per urto delle onde contro le roccie della costa, b) secondo altri (11) invece la formazione del minerale sarebbe stato iniziato dalla decomposizione delle alghe e si sarebbe continuato nella guisa dei soliti depositi chimici.

Ognuna di questi ipotesi è stata confutata nel lavoro originale con tutti gli argomenti a mia disposizione. Die essi mi limitero ad accennare i principali:—

A) La pelagosite è stata da me ritrovata nelle Isole Tremiti (Cretaccio, S. Domino) sul calcare nummulitico e anche sui noduli di marcassite, pro-

fondamente limonitizzata, e sulla marna gialla. La letteratura ci dice inoltre che la pelagosite fu ritrovata su roccie feldspatiche della Corsica (13) e su roccie scistose alternanti a quarziti nella provincia di Orano (12) ecc. L'ipotesi 2 e 3 non sono perciò sostenibili.

B) La pelagosite trovasi oltre che in chiazze più o meno estese ed irregolarmente distribuite, anche in goccioline *isolate*, sparse sulla superficie delle roccie calcaree o nascoste nelle piccole cavità d'erosione del calcare stesso, esse inoltre non possono ritenersi come residuo di intere croste gradualmente distrutte dall'erosione dell'acqua.

Queste osservazioni e la struttura stratificata delle goccie (semplici o multiple) sono argomenti sufficienti per escludere la ipotesi 4. Infatti come si potrebbe spiegare l'accrescimento di goccie isolate e stratificate ammettendone la formazione per essiccamento di spruzzi schiumosi, irregolarmente lanciati dalle onde infrangentisi contro gli scogli durante le tempeste? Nello altro caso poi, perchè mai la pelagosite non dovrebbe trovarsi sviluppata in modo continuo anzicchè in chiazze e soltanto su alcune coste?

Inoltre è da domandarsi se veramente il calcio si trovi disciolto nel mare come carbonato: esperienze in proposito sembra dimostrino tutt'altro (14) perchè il carbonato di calcio portato nell'acqua del mare dai fiumi, diminuisce rapidamente sotto l'azione della vita (15), perciò il Werdnadsky sostiene che detto sale si depositi dall'acqua del mare solo come carbonato di calcio biogene.

Per tutte queste considerazioni mi si affacciava perciò l'idea che la palagosite fosse dovuta ad un'attività vitale: l'idea mi venne altresì suggerita dalla costante presenza dei resti vegetali, e la migliore conferma mi venne dal riconoscimento del gen. Chroococcus. Il Chroococccus è un genere di alga fissa calcaridera che può dar luogo a formazioni oolitiche, come quella del Sinai studiate dal Rothplez (16.)

Questo genere vive tra le alghe verdi fisse, anche se non calcarifere, le quali vengono incluse nell'incrostazione di carbonato dicalcio secreto dai Croococci. Si spiega in questo modo la presenza delle Scytonema, che, per quanto mi risulta, non sono alghe capaci di fissare il carbonato di calcio. Se alla formazione della pelagosite concorrino altre alghe, non ho potuto stabilire con sicurezza. Certo la differenza di struttura tra il nucleo e la zona esterna delle goccie pelagositiche fa ritenerlo molto probabile.

Una nota del Fossa-Mancini (17), seguita alla mia, pone in rilievo l'importanza delle percentuali di stronzio per la decisione definitiva della origine della Pelagosite. L'A. si orienta dapprima verso la mia ipotesi perchè, citando una ricca letteratura, sostiene che la percentuale di SrO da me trovata è troppo alta per ritenerla ottenuta dall'acqua del mare senza il concorso di un'attività vitale. Perciò secondo il Fossa lo stronzio potrebbe ritenersi dovuto a casuale inclusione di spicule di Acantari oppure alla

attività vitale di alghe capaci di fissare sali di stronzio oltre il carbonato di calcio e tra queste potrebbe anche entrare il Chroococcus.

Per decidere in proposito non è sufficiente una semplice analisi microscopica, sarebbero invece necessarie esperienze. In ogni modo qualunque ne fosse il risultato, la ipotesi della origine biochimica della pelagosite non potrebbe essere contraddetta: infatti in un caso lo stronzio nella sua rimarchevole percentuale, non porterebbe alcuno argomento in favore o in contrario all'ipotesi, nell'altro non farebbe che confermarla. Nella conclusione però il Fossa-Mancini riapre la questione perchè affaccia la possibilità che nella roccia su cui si è depositata la pelagosite, possa trovarsi lo stronzio (come solfato o come carbonato), in proporzioni pressocche identiche a quelle trovate nella pelagosite. Perciò consiglia un'analisi chimica del calcare, e nel caso di un risultato positivo, secondo l'A. si dovrebbe riprendere l'ipotesi del Rosemont (ipotesi 3.) Per conto mio non credo alla possibilità affacciata dal Fossa e qualora mi sbagliassi in ciò, considererei sin da ora una simile corrispondenza soltanto come una molto singolare casualità. Infatti l'ipotesi del Rosemont non può oramai riprendersi in considerazione per le ragioni che ho già dette. Anzi aggiungo che la pelagosite fu anche ritrovata su lave basaltiche della Riunione (18), sulle quarziti della baja d'Antegren (19), sul quarzo dell'Isola Rossa (21), sull'ortoclasio del granito dell'Isola d'Elba (20), sulle pietre verdi dell'Isola Rossa (21.) L'unica ipotesi che meglio si accordi con le osservazioni fin ora fatte sulla pelagosite, resta ancora quella della origine biochimica da me avanzata.

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ABSTRACT.

On the Nature and biochemical Origin of Pelagosite.

The Author gives an accurate historical and critical explanation of the important subject referring to the results of microscopical and chemical research, and he concludes that pelagosite (sea-weed) is a conglomeration of aragonite with very impure fibrillous-crystals caused by inorganic salts and sea weed-decomposition with partial fibro-radiated concentrical structure of biochemical origin. The question of the organic origin of the pelagosite is discussed at length, and the author is of opinion that such an origin arises from the action of a calcigerous sea-weed of the *Chroococcus* species, probably with the help of other calcariferous weeds as may be inferred from the difference of structure of the nuclear and the outer zone of the pelagositic drops.

This biochemical origin is proved by the presence of small quantities of strontium which result from the analysis.

SECTION VI.

RIFT VALLEYS.

36. RIFT VALLEYS AND LAKE VICTORIA.

BY

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CONTENTS.

I. INTRODUCTION.

Nobody can be more acutely aware of the shortcomings of this paper than its author. The subject it deals with—or, one would rather say touches upon—is an immense one. Properly understood it involves the entire

geologic history of Eastern Central Africa since the disturbance of the African Peneplain in (probably) late-Cretaceous or early Tertiary times. Nor it that all, for as investigation proceeds it becomes increasingly probable that the forerunner of Pleistocene events that gave rise to those spectacular features of the rift valleys, much as we known them now, had their beginnings in exceedingly distant days, may be in pre-Cambrian times.

There is much to be learnt about African geology, even with regard to fundamental matters, and one of the many puzzles to be solved relates to conditions which, with cyclic repetition, have permitted of long continued sedimentation resulting in the deposition of great thickness of strata in inland basins.

Africa, perhaps, has had a history peculiarly its own. However that may be, one may reasonably doubt whether elsewhere on this planet widespread and long continued stability and subsequent large scale movement, with its accompanying fracture and volcanism, have played a more important part in the moulding of present-day topography.

So many lines of research can be brought to converge on African rift valley problems that it is hopeless to attempt even to touch upon them all within the compass of a single paper; and in an endeavour to treat the subject with reasonable adequacy in a short essay such as this, one is assailed from the first by a sense of inevitable defeat.

Several important aspects are passed over in the following pages for want of space, and climatic changes that have left their marks on the rift valleys are dismissed in a few words. A fuller account of them will be found in a paper by the present writer dealing with the Geology of Uganda and Kenya in a Handbook on the Geology of Eastern and Central Africa now being prepared by the African Surveys Sub-Commission of the International Geological Congress (1929); but that account leaves much to be said. References to that publication in the following pages are given thus: (Handbook).

References to the publications mentioned in the text and listed at the end of this paper are given in brackets; while reference to *paras*, also given in brackets but in italics, refer to paragraphs in the body of the paper.

The term *rift valley* is used in this paper to denote depression, relative, or actual for which faulting is directly responsible—irrespective of the nature of the faulting. *Rift faults* connotes faults responsible for a rift valley.

II. Physical Features.

1. In order to understand the late geological events about to be described it is necessary to appreciate, if only in a broad and general way, the physical features of the area to which this paper has reference. To the present day tourist Kenya and Uganda are two entirely different coun-

tries. The former being one of hot coastal lowlands and invigorating highlands of astonishing beauty, while Uganda is a vast area of plateaux separated from each other by innumerable wide valleys choked with papyrus. These pictures are incomplete but they are typical.

2. GREGORY (6, p. 222) has shown that Kenya Colony and Protectorate—late British East Africa—is devisable into seven zones which, starting at the coast and working inland, are:—

(1) The *Temborari* (a Swahili name for the coastal plain.) This is a lowlying plain consisting of raised coral reefs and marine sands, some shell beds and alluvium with occasional outliers of the next zone. It is of no great width in Kenya, averaging perhaps about twenty-five miles. It is deeply indented by branching estuaries bordered by mangrove swamps and on its seaward margin there are lines of sand dunes.

The next zone—the Foot plateau—is also narrow and commences very near the sea where the railway enters it at Chamgamwe. It is an undulating plateau, generally well cultivated. The underlying rocks are sedimentary and date from Permian to Jurassic (Corallian) times.

The third zone is well known as the *Nyika*. The name is a Swahili one and is generally considered to mean a wilderness, which indeed the area is. It is an almost waterless plain in the dry seasons, and supports a characteristically thorny xerophytic flora. The underlying rocks are those of an ancient, almost certainly pre-Cambrian, crystalline complex. The soil is sandy and generally red.

Rising from the *Nyika*, and forming its western boundary in places, is the *Primitive Mountain Axis*, regarded by GREGORY as the remnants of a one time mountain chain which stretched from the Drakensberg to Abyssinia if not beyond. It, too, is formed of rocks of the old complex. The last of GREGORY's zones is the *Rangatan*, this being the native name for the wide volcanic flat lands on which Masai grazed their cattle. The Rangatan consists of lava sheets now forming great upland plains of which those of Kapiti and Athi are the best known. Rising from the volcanic sheets of the Rangatan which is the whiteman's country of Eastern Central Africa, are the giant volcanoes of Kilima Njaro and Kenya.

Through the Rangatan runs another zone, that of the *Great Rift Valley*.

3. It is necessary for the purpose of the present discussion to add another zone. This may be called the *Nyanza zone*. It consists of the plateaux and papyrus country, so typical of Uganda, and Lake Victoria. It is poorly represented in Kenya, partly because it is in great measure obliterated by the lavas of the Rangatan.

4. Whereas all the zones previously mentioned have their own geology, not excluding the rifts, for these are floored by late Tertiary and Recent sediments, the Nyanza zone is underlain by rocks of many different kinds and ages, but volcanic rocks are typically absent from it. The rift valley pierces the Nyanza zone just as it does the Rangatan. These two zones therefore are of special interest in the present discussion.

5. Not only do the rocks present in the Nyanza zone vary from place to place in respect of kind and age, but they are much faulted and present many complicated structures; low dips, although presented by the less ancient deposits, are of local occurrence, and most of the beds are steeply inclined. From these facts it is clear that the plateaux are remnants of a peneplain.

6. While it is hardly necessary to say that denudation of the old plain has been brought about in the main by two factors, namely rivers and subaerial agencies, the work of the latter being initiated in large measure by the declivities consequent upon the action of the former, it is desirable to call attention to a significant difference in the results of these forms of erosion. The tendency of the main channels of the rivers is to run right across the country, shaping their courses with relatively little reference to topographical structure, while subaerial denudation has been controlled by it. Thus, for instance, in the south-west of the Protectorate there are large punchbowl areas which are structurally domoid and consist essentially of very ancient sediments dipping steeply away from central cores of granite, the whole having at one time been levelled off by the peneplain. These are typically developed in the Ankole country and in the adjoining parts of Tanganyika Territory, and have been called arenas (22); rivers, such as the Ruizi, run right across the arenas, cutting their way through the mountainous country that separates these relatively low-lying areas. This can only mean that the course of the rivers was determined before the development of the arenas, the walls of which rise one or two thousand feet above the floors; and that elevation has slowly proceeded as the rivers have cut their way downwards. It is to be noted, too, that the highest plateaux lie to the south-west in Uganda and that the higher the plateaux the deeper the river valleys. In other words the westward activity of the peneplain, now elevated to form a (dissectedly) plateau, is greater than that of the river valleys. This, as we shall see, is a consequence of slow uplift in the direction of the rift valley.

7. Neglecting exceptional eminences such as occasional residuals on the peneplain, volcanic cones (the Mufumbiro mountains and Mt. Elgon) and the upthrust mass of Ruwenzori, one may say that mean altitudes in Uganda decline in a north-easterly direction towards Chua and Karamoja, when the general level is nearer 3,000 than 4,000 feet, but it rises again on the north-eastern borders of the Protectorate towards the rift valley in Kenya. The lowest point in the Protectorate is less than 2,000 feet at Nimule, on the Sudan border, where the Nile makes a remarkable acute

bend to the north-west—a line which is carried south-eastwards into Uganda by the course of the Aswa river.

8. Perhaps nothing is more astonishing in this country of topographical surprises than the disposition of the rivers. Four facts are particularly striking. One is that all the main channels are of the nature of through valleys connecting Lake Victoria with the western rift; the second is that the orientation of the tributary valleys is that appropriate to westerly flowing main channels; the third is that the river systems tend to be drowned towards the east (Lakes Kijanebalola, Wamala and Kyoga for example); and the fourth is that in spite of their westerly orientation some of them, the Kagera, the Ruizi and the Katonga flow easterly into Lake Victoria, notwithstanding the through valleys which connect that lake with those of lower altitude in the rift.

9. Further inspection reveals four other important points. One is that although a number of the tributaries of the Kyoga system rise within a very short distance of the shores of Lake Victoria only one taps its waters. That is the upper Victoria Nile which leaves the lake by way of the Ripon Falls and is a very juvenile stream; and it may be added that the drainage of Kyoga into Lake Albert is through another equally juvenile stream, the lower Victoria Nile, which enters the rift by way of the Murchison falls.

10. The second point is that each of the apparently westerly flowing streams which really flow to the east—that is the Rufua-Kagera, the Katonga, and the Ruizi—emerges from a swamp which functions as a divide in their through courses; each of those swamps is about twenty three miles from the western rift (measured along normals to the scarp); and from the western side of each swamp-divide a westerly flowing stream emerges. The divides are situated on the crest of a low arch-like bulge that descends westwards to the escarpment edge. It is clearly of the same nature as Willis' twin arches of the Dead Sea depression (27).

11. The third point is that in spite of the fact that the through valleys are very old features, only the long easterly flowing components of the waters they contain are senile and almost dead, while the short westerly flowing streams are, like the upper and lower Victoria Nile, extremely juvenile and active. This statement requires some qualification, however, for the upper courses of the easterly flowing streams in the south-west—the Kagera and the Katonga are somewhat juvenile.

12. The fourth point, as A. D. Combe of the Geological Survey of Uganda was the first to point out, is that just as some of the tributaries of the easterly flowing streams are drowned (e.g. Lake Wamala), so entire sections of the Kagera, and the Katonga rivers are submerged by Lake Victoria, while the indentations which surround this astonishing lake, and the channels which separate the islands in it, are drowned valleys.

13. A few words about the rift valleys are necessary: The term Great Rift Valley is a misnomer and *rift valley system* was used in 1921 (23) to replace it. It is not one great valley but a series of valleys so aligned as to indicate genetic association rather than actual continuity. The general trend of the system is N.-S., although individual members deviate as much as 45°, and in rare cases nearly 90°, as for example the Kavirondo depression at the western end of which lies the Kavirondo Gulf.

14. Neglecting the great N.W.-S.E. trough of the Red Sea, which may be said not to lie in Africa, the rift system in the continent is naturally sub-divided into two sub-systems which may for convenience be called the Eastern and Western Rifts. Each has a curious geometrical form and is approximately the inverted and reversed mirror image of the other. It is as though one were the picture of the other as seen on a focussing screen of a camera. The western rift is like a crosier or a question mark carelessly made the wrong way round.

15. Starting south of Lake Nyassa and running more or less due north, it bends round north-westerly in the vicinity of Rukwa, north-north-westerly and northerly through the Tanganyika rift, north-north-easterly then north-easterly through the Kivu, Edward and Albert Rifts. The eastern rift (starting from the northern end) runs down from the vicinity of the junction of the Red Sea with the gulf of Aden in an approximately south-west direction to Lake Rudolf where it turns southerly, then south-south-easterly and then southerly again through the main rift valley of Kenya and finally swings round south-westerly through Lake Natron, in Tanganyika Territory, into the Eyasi depression. In the centre of the roughly circular area enclosed by the crooks of these two sub systems the great Nyanza, than which, probably, no more remarkable lake exists, lies athwart the equator.

16. It would appear then that, although Lake Victoria is not itself a rift, it is intimately connected with the fault-formed valleys that make up the system, and is, in some way or other, the connecting link between the eastern and western components.

17. It seems fair to assume that the eastern and western rifts do not differ materially in mode of origin—what one is, so essentially, one would suppose, is the other. Nonetheless there are marked differences between them, and attention has more than once been called to this fact (23, 25 and 18).

18. Broadly speaking, the eastern rift suggests a collapsed zone while the western rift does not—to be more specific, the eastern zone is irregular, in that the scarps deviate considerably from straight lines and they tend to be discontinuous. There are numerous transverse embayments and there is not one boundary scarp on each side but many scarps one below another, and the faults which they indicate extend to the centre of the trough. The whole is closely associated with volcanic phenomena.

19. Not so with the western rift in Uganda, of which the Lake Albert depression may be taken as typical. There the scarps are astonishingly straight for long distances and transverse embayments are typically absent. The two opposing scarps delimit the rift with precision so that one may speak of the rift faults and the rift block that lies between them. The western rift zone in Uganda is characteristically not one of volcanism. There are too, other important differences between the eastern and western rifts and the more significant among these will appear in the following pages.

III. Geological Column.

20. The following is a much abridged representation of the non-igneous formations present in Uganda and Kenya.

Periods.	Formations.	Remarks.
Recent.	Alluvium, beaches, etc.	
Pleistocene.	Upper part of a sedimentary series (if not the whole of it) known as the Kaiso beds in the Albertine depression, and the Pluvial gravels which succeed them.	(1) At the top of the Kaiso series are some bone-bearing horizons which mark a period of desiccation.
	Terrace gravels, old beaches and the Kamasia beds of the Eastern Rift (13); raised coral reefs and some other marine deposits at the coast, etc.	(2) There are some sub-aqueous volcanic tuffs in the Albertine depression which belong here, and interbedded with the volcanics of the eastern rift region there are lacustrine deposits some of which must be Pleistocene.
		(3) The age of part, at any rate, of the sixfold volcanic succession established by Gregory in Kenya (7, p. 105) must be revised since in his *Nyassan* the Kamasia beds, are placed. They were originally regarded as Miocene, but have now been proved to be Pleistocene.
		(4) The Kaiso bone-bearing beds which were supposed at first to be Plio-Pleistocene (26) and Oswald's Pliocene are now regarded as middle Pleistocene (11).

Periods.	Formations.	Remarks.
Pliocene.	Perhaps the lower part of the Kaiso beds and/or part of the Kisegi beds beneath them belong here. Also some of the lacustrine deposits interbedded with the volcanics of Kenya; and some marine beds at the coast.	(1) Some of the ancient river gravels must be contemporaneous with the Kisegi beds.
Miocene.	Judging by the mammalian fauna the lacustrine deposits at Karungu (Handbook) belong here. Also other beds of this series found this year by the writer at Rusinga Island, and some others at Koru near Tinderet in Kenya. *Dinotherium* remains have recently been claimed from what are presumably Kisegi beds on the western side of the Albertine depression (the discovery has not yet been published).	(1) It is to be noted that in spite of the Miocene facies of the vertebrate fauna of the Karungu beds, all the molluscs recovered therefrom are living species (although no longer living in the lake); and the possibility of the "Miocene" being in reality of later date has to be considered. (2) Some ancient gravels probably belong here.
Oligocene.	No Oligocene lake deposits have been proved in Uganda. It is possible, however, that beds of this age may underlie the Kisegi beds (the true base of which is unknown). But it is not very probable. Some of the gravels associated with the peneplain are no doubt of this date.	(1) It is likely that the main uplift of the African peneplain began in the Oligocene although it was probably disturbed before that date.
Lateritic Blanket.	This is a partly chemical and partly residual ironstone formed during a very advanced stage of peneplanation. It is remarkably well developed in Uganda, but less well developed in Kenya.	(1) Peneplanation must have been proceeding for a very lengthy period—probably since Triassic days. The peneplain is of great importance and its surface, now elevated to a plateau, can be used as a datum just as a geological stratum can. Although it was not disturbed on a grand scale till Tertiary times, disturbances appear to have begun in the Cretaceous.

Periods.	Formations.	Remarks.
Eocene.	Some fossiliferous beds of this age are known at the coast. They do not appear to be extensive.	
Cretaceous?	A local development of sandstones and conglomerates, etc., known as the Bugishu series occurs in Uganda near Mt. Elgon. They appear to be consequent upon a local disturbance of the peneplain. Fossil leaves and fruit have been discovered. They have not yet been specifically identified, but they are tentatively regarded as upper Cretaceous.[1]	(1) Interbedded with these beds are some volcanic tuffs; they probably mark the beginnings of volcanicity in the Elgon area. (2) The Kapitian eruptions of Kenya are regarded by Gregory as probably late Cretaceous in age.
Jurassic.	Shales and limestones of Bathonian to Corallian age are known in the coast belt of Kenya.	
Permo-Triassic.	Here are included the Duruma sandstone series of the coast belt and the Karroo deposits of Uganda.	(1) The Bugishu sandstones were tentatively regarded as Stormberg until their much later age was proved. (2) The Karroo beds of Uganda, so far discovered, are of Ecca age.
?	The Bukoba, Mitiyana and Butulogo sandstones of Uganda and the Kisii sandstones and quartzites of Kenya.	(1) These three separate developments—they occur in different districts, from which they are named—are provisionally grouped together. The Kisii and Bukoba sandstones are almost without question contemporaneous deposits. All appear to be unfossiliferous. They are of great but unknown antiquity, except that they are post-Karagwe-Ankolean.

(1) As this goes to press a communication from Mr. W. N. Edwards of the British Museum (Natural History) makes it plain that the fossil plants from Busoba leave the age of the rocks a matter of uncertainty. They may be Tertiary.

Periods.	Formations.	Remarks.
Pre-Cambrian.	Karagwe Ankolean. This is a very thick series (over 20,000 feet) of now considerably altered sediments which are almost certainly of fresh water origin. They occur in Uganda, particularly in the south-west, and in Kavirondo (Kenya).	(1) The Karagwe-Ankolean of Uganda exhibits a northern (Bunyoro) and southern (Ankole) facies. The former is less metamorphosed than the latter which has suffered intrusion of granites. It is possible that the northern facies is younger than the southern and may be Transvaal in age. (2) In the northern development there are tillites, while seasonal banding occurs in the southern development where no tillites are known.
Pre-Karagwe Ankolean post-Archaean.	These are metamorphosed conglomerates, phyllites and igneous rocks, some of which appear to have been andesites.	(1) This series, though not known to be very well developed anywhere, is at present best seen in Kenya (Kavirondo) some ancient deposits in the mass of northern Ruwenzori probably belong here.
Archaean.	Basal complex. This is the usual assemblage of schists, gneisses, quartzites and limestones. It includes representatives of both sedimentary and igneous rocks, all of which are highly metamorphosed. Beds of the basement complex are widely distributed in Uganda and Kenya.	

IV. Rift Valley Hypotheses.

(Of these only two will be considered; one is Gregory's tension theory and the other the compressionist view).

A. *The Tension Hypothesis.*

21. (a) *Essentials.*—Bereft of all but essentials Professor Gregory's Tension theory of the African rift is as follows:—

(1) Associated with the secular movements of late Cretaceous times, that resulted in the vast outpourings of lava now known as the Deccan traps of India, were similar events on the other side of the Indian Ocean.

(2) These, in East Africa were the hunching up of the continent, which had long been stable, into a low arch of great linear (N-S) extension. The high plateau, thus formed, was necessarily stretched and "traversed by a double series of lines of weakness crossing one another like a network" (6). At the intersection of these lines magma, pressing up from below, forced its way through and was extravasated in the form of lava thereby giving rise to plateau eruptions which covered vast areas.

(3) The out-welling of the lavas destroyed the stability of the country, for the reservoirs were empty and masses of volcanic material had been piled upon the surface. The upper parts of the earth's crust were therefore over weighted above and weakened below and earth movements were necessary to restore equilibrium.

(4) These movements manifested themselves as subsidence east and west of the zone now occupied by the rift valley. As subsidence proceeded the central arch, thus left standing, began to suffer stress in consequence of the gradual removal of lateral support, and strain manifested itself in lateral cracks which led to subsidence between these, particularly after renewed volcanism re-introduced the conditions outlined in (3) above.

22. GREGORY, it is true, found it desirable at a later date to introduce other factors to account for continued tension, and for the existence of rift valleys unassociated with great volcanic outpourings and the present writer (24) indicated how this would follow upon, and continue long after, the hunching up of Africa—supposing that to be due, as Gregory did, to the foundering of part of a one-time continent (Gondwanaland) which had occupied the Indian Ocean. But these are rather matters of detail, and do not effect the essential mechanics of the hypothesis.

23. The sequence of events as worked out by GREGORY (1921 p. 105) and later confirmed by SIKES (18), together with the apparent absence of all faults in connection with the Rift Valley in Kenya, other than those which are structurally normal, strongly supports the Tension hypothesis; and it is not an unjustified assumption that if this important section of the rift valley is a consequence of lateral tension so in all probability is the rest of the system. So far as Kenya alone is concerned the hypothesis is on the face of it sound; but is it applicable elsewhere? and is it not possible that excessive volcanism may have fogged the issue? in other words may not volcanic extrusions and associated collapse be a secondary issue consequent upon major tectonic events that gave rise to the rift valleys?

24. (b) *Imperfections.* The adequacy of volcanism to explain the phenomena of the rift, and its importance as a pre-requisite to rifting were shewn in 1921 (23) to be questionable, and if the tension hypothesis was to be retained it became necessary to introduce continued tension, apart from that due to lateral stress resulting from subsidence, for it was shewn that with regard to the western rift in Uganda volcanism had played a negligible part; except in the extreme south-west. The Albertine rift is not bordered by volcanic rocks; and igneous ejectima are only known on the highlands of Toro to the east of Ruwenzori. These take the form of volcanic tuffs, some of them subaqueous, ash and tuff cones and explosion craters. They are of very late date and came into being long after the rift first appeared but not after rift movements had ceased—if indeed they have ceased. Moreover, the craters are arranged on lines that strike across the direction of trend of the rift and parallel those of the faulting of long pre-rift date. They probably overlie such faults.

25. This, of course, does not exclude lateral tension as a causal factor in the formation of the rift, it merely excludes volcanism from that category. There are, however, other facts that do not favour tension. They have been previously described (23 and 25). One is that the western rift cuts across a system of pre-rift faults that make an angle of about 20° with it. These can be shewn to be lines of weakness, and they should have controlled the direction of the rift under tension, another is that Ruwenzori is nearly encompassed by rifts, and on the tension hypothesis it was regarded as a mass left more or less undisturbed when the surrounding country collapsed along normal faults. Standing as it does in a zone of which subsidence is supposed to be a characteristic feature, the mountains should, on this view, have been in a particularly unstable position and should itself have collapsed. It could, of course, be argued that, for all we know to the contrary, it has subsided to some extent; but there is an objection to this view, as will be apparent later. Assuming it to be true, however, then the original altitude of the country, before its postulated subsidence, must have been greater than that of Ruwenzori to-day. It would, therefore, have been glaciated, and evidence of that one-time glaciation should be observable on the relatively low-land flanking the great mountain, but no trace of it can be found.

26. On general grounds, such as the above, the tension theory was found to be inadequate to explain the western rift and nine years ago the writer suggested another hypothesis.

B. *The Compression Hypothesis.*

27. (a) *Essentials.*—Investigations, both in Kenya and in Uganda, left no possible room for doubt that the rift valleys owed their existence directly to faulting, and although there was no escape from the view that

the rift bottoms had moved downwards, relatively or actually, tension seemed to be incapable of explaining the phenomena presented by the western rift. An alternative was sought. It was considered that a distinction should be drawn between primary and secondary features of the rift valleys, and it was considered that normal (step) faulting, so admirably exhibited in Kenya, belonged to the latter category.

28. It was clear that Gregory's emphasis on the importance of the uplift of Africa as the first link in the chain of events that led to the formation of rift valleys was fully justified; and a decade ago, as hitherto, this uplift was considered to be due to the foundering of Gondwanaland. Subsidence of a great land mass would in all probability lead to lateral thrust of which the hunching of Africa might be taken as evidence. Why then should not the thrust give rise to compressional fractures of which the rift valleys were the surface expression?

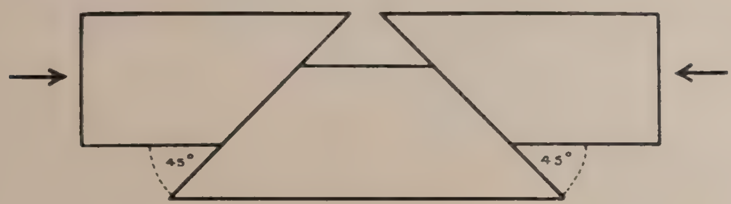

Fig 1. Diagram to illustrate the mode of fracture of a test-piece of stone or cast-iron under end-compression.

29. Reference to such works on mechanics as were available in the then somewhat remote Protectorate of Uganda, and subsequently to DAUBRÉE's studies (3) led to the view that compression was capable not only of explaining the rift valleys, but of removing the difficulties that beset the tension theory, and for those reasons the present writer proposed the compression hypothesis.

30. The essentials of that hypothesis were these:—

(1) Lateral compression (consequent upon thrust exerted by Gondwanaland during its subsidence) hunched up and warped large areas of Africa, so that Kenya and Uganda and the Congo represented a geodome on which there were two low arches separated by a relative downwarp in which waters accumulated to form Lake Victoria. (These events were considered to be due to a slow movement during the early phases of the Gondwana subsidence). Later (during an accelerated phase of the continental foundering) movement became too rapid to overcome the enertia of great masses of Africa and

gave rise to continued warping, therefore fracture took place along opposing faults splayed at 45° to the direction of pressure. Therefore the two arches fractured and opposing (overthrust) masses glided up along the facture planes while the block between them was squeezed down. In this way, it was considered the rift valleys were formed. As the rift blocks were pressed down so the demands of gravity led, where necessary, to adjustment along the overthrust rift sides by step-faulting. A consequence of this was the burial of the true (primary) rift faults by inslipping ground (*vide* 23, diagram p. 353).

31. Ruwenzori was regarded as a block squeezed out by compression just as the rift blocks were squeezed in. The mountain, in fact, was, so to say, a rift valley upside down.

32. The whole explanation was tentative and the concluding paragraphs of the paper on the subject contained the following: "The compression theory is really a working hypothesis which, like any other, must stand or fall by the results of future enquiry."

33. (b) *Imperfections.* During the last nine years many facts bearing directly and indirectly on the nature of the western rift have been brought to light, and, in the writer's view, the compression hypothesis still holds the field; but in several ways it must be stated very differently. At the time of its first appearance in print, however, the opposition raised was of the general nature, and in particular it was widely held that compression should have given rise to folded and overthrust coastal ranges rather than to rift faulting in the interior of the country. But this objection did not seem to be of much weight for the compression that necessitated rifting was regarded as more or less deep seated and as acting upon the solid rocks of the basement complex, and not as a force of shallow origin compressing poorly solidified sediments.

34. A much more serious objection, however, and one which did not seem to be generally recognised, lay in the nature of the reversed faults. They were visualised as plunging down always at about 45° through the whole thickness of the continent—this deep penetration being necessary in order to permit of the rift block underthrusting the Congo scarp, for the pressure was regarded as acting from one side (the S.E.) only. The existence of such faults is improbable, and the forces involved on the underthrusting would have been stupendous and could not have been derived from lateral thrust exerted by the subsidence of Gondwanaland. While the faulting was, in my view, probably deep seated there is no good reason for regarding it as excessively so, and it is probably not unlike that exhibited by some Scottish highland structures, and therefore to be conceived in the manner of WILLIS' ramps; that is to say as flat thrusts rising at one end steeply surfacewards (27).

35. It would almost seem that some geologists hold tenaciously to the tension hypothesis for no better reason than that it apparently supports another theory—that of continental drift.

V. Later Work.

A. *Kenya.*

36. (a) *Volcanism and the Rift.* In 1926 Sikes (18) published a very important paper dealing with the eastern flank of the rift valley near Nairobi. He confirmed Gregory's view (6, p. 105) that the volcanic outpourings in Kenya can be classified into six age groups. This sixfold grouping does not call for question, but the chronology adopted can no longer stand. (*vide* Section III).

37. Sikes further shews how collapse has repeatedly followed volcanic extrusion, but in one place (loc. cit. p. 400) he says:— "It is conceivable that the formation of the Rift valleys as structural features antedated the first eruptions; in fact where unrejuvenated flanks of the valley in Kenya are composed of ancient metamorphic rocks they are generally gentle slopes more deeply eroded then even the earliest lavas." He calls attention to and describes in detail the development of grid structure in the lava country, and in that connection makes the following significant remarks: "Examination of the steeply sloping and sinuous gorges carrying the discharge down the escarpment from the adjacent summits of the floors of the long southward-sloping valleys of the grid, has failed to reveal meridional faults with throws up to 400 feet. If the walls of the valleys of the grid were formed by faults having throws comparable with their heights, one would expect to find evidence of it at this locality. Minor gravity faults, with throws up to 50 feet, are not infrequent, but are often not in continuation of the cliff faces of the grid. The tilting of the blocks, so that the resolved components of the dips of their lava sheets in a westerly direction now varies from 1° to 10°, is undoubtedly the result of fracture and bending, of the nature of gravity faulting along north-south planes of weakness, but the movements seem inadequate to account completely for the present form and depth of the deeper valleys. In other parts of the Rift Valley flank, cross valleys show gravity faults of considerable throw, striking north and south, while small ones are frequent; but, in the case of the majority of the deeper valleys of the grids, the writer is of the opinion that the evidence indicates that they have been initiated and partly developed by gravity faulting and jointing and that they have been deepened and widened by erosion."

38. What, it may be asked, about the rift valley beyond the limits of this volcanism? and what about the steep-sided escarpments of Lake

Albert? They do not owe their origin to the accumulated effects of erosion and shallow gravity faulting. It would seem that while the details of the original configuration of the rift in Kenya has been obscured by volcanism collapse and erosion, the original fault-formed valley has controlled their effects.

39. SIKES is a firm believer in the tension theory, at any rate so far as the eastern rift in Kenya is concerned, but he is not prepared to be dogmatic with regard to the rift valley system as a whole for he says, "A study of the physiography of a very small section of the Rift Valley system without correlation of other parts is necessarily inadequate to justify any attempt being made in this paper to examine the theories which have been advanced to account for the stresses which gave rise to the East African Rift Valleys," and the modifying influence of volcanism is also recognised thus:—" It will be seen that the eastern flank of the Rift Valley in this district—and indeed the western flank also . . . is of a very different character from that of most of the major troughs of the Rift Valley System, where volcanism either has not manifested itself, or has been of minor importance; for one finds the flank composed of a " grid " of small parallel ridges and valleys, which have been designated " miniature rift valleys," in place of flat-floored depressions, confined within two boundary walls, as in the case of the Nyassa, Tanganyika, Albert and Edward depressions."

40. (b) *Tectonics of the Coast Belt.* Another recent contribution which cannot be passed over, even in a short resume such as this paper, is one by PARSONS (17) who worked for a considerable period in the coastal areas of Kenya. PARSONS, like GREGORY and unlike the present writer, still holds to the Gondwanaland subsidence theory, but unlike GREGORY, and like the present writer, he supports the compression hypothesis.

41. He claims to have established the existence of numerous overthrusts in the coastal sedimentary rocks and says (*loc. cit.* p. 94):—" The formation of the unique orographical features of Africa instead of the formation of mountain structures must be attributed to similar, *i.e.*, tangential forces, acting under different conditions, and not to exceptional types of earth-movement. It is generally accepted that one of the primary conditions necessary for the formation of folded mountain structures, is that the area should have been one of recent heavy deposition, and contain extensive deposits in a relatively unconsolidated condition. Such were not present in this region, but it was an area of exceptional stability and consisting largely of rocks, which had been thoroughly consolidated and had long formed a land area. Consequently, instead of rocks folding, they fractured and gave rise to reversed faults which with subsequent volcanicity and denudation, has given rise to the unique land forms seen along the Rift Valleys."

42. There are those who would dispute the overthrusts which PARSONS claims to have mapped in the coast belt, on the ground that it is nearly

always the younger rocks that are said to be overthrust upon the older. But it must be admitted that PARSONS has done more detailed work over wide areas of coastal Kenya than anyone else, and the most that unbelievers can do at the moment is to suspend judgment.

43. (c) *The Nandi Escarpment.* This is a topographic feature to the south-east of Mt. Elgon. It is necessary to mention this because there is some confusion with regard to the name. GREGORY, following HOBLEY (7, pp. 123 and 130) uses it to denote the northern escarpment of the Kavirondo depression and calls the feature here referred to as the Kakamega scarp. This nomenclature has not met with general acceptation and will not be adopted here. ÖDMAN (15, p. 89) says:—"Besides Mt. Elgon and the Samia Hills, Nandi Escarpment is the most conspicuous topographical feature in the district. It emerges in the dense Kapwaren Forest east of Kaimosi and runs in a northerly direction for about 30 km. and then turns in a N.N.W.—N.W. direction towards the Elgon volcanic mass. At Brodrick Falls the Nyoja River breaks its way down the hills and some kilometres further on, the escarpment dwindles away and disappears before reaching the mountain."

"The Escarpment raises its hilly crest 300—500 m. above the underlying plain. The development of highly sheared gneisses and even mylonites along the escarpment indicates a fault line. When approaching the escarpment from the West one observes in some places an increasing foliation and schistosity. That is the case E. of Kaimosi and at Malaba Mission Station N. of Kakamega, etc.

"The southern and central portion of the escarpment is mainly composed of different gneisses. Whether any rocks of a sedimentary origin appear in these parts is uncertain. The time spent in investigating the Nandi Escarpment was far too short for any close research. It is quite possible that the rocks of the supracrustal series continues to strike across the fault line."

44. And again (*loc. cit. p.* 80):—

"The survey in the Kavirondo District revealed very interesting rocks but of quite another character to those in Mt. Elgon District.

"The rocks of this area are characterized by their unaltered conditions.

"They hardly seem to have met with any regional dynamic metamorphosis at all. Only along the fault-line of the Nandi Escarpment the rocks are locally turned into gneisses, schists and even mylonites."

45. It is interesting to note that the S.E.—N.W. portion of the scarp would, if projected north-westerly, run into the remarkable straight line of the Assua river which is carried on by the S.E.—N.W. reach of the Nile already referred to (*para.* 7). Well founded report has it that along that reach flinty crush rocks occur.

46. The Nandi escarpment is one of the fracture lines associated with the rift; and there is as yet unpublished evidence that seems to indicate that the Nzoya river has cut its way down as the escarpment has risen.

B. *Uganda.*

47. (a)*Features of the Albertine Rift.* An important feature of the Albertine depression, and of Ruwenzori, is the existence of hanging scenery; and another feature which needs to be noted here is the occurrence of certain tectonic structures within the rift itself.

48. On the Uganda side of the Lake Albert depression (the Congo side has not been so well studied, but it is known that hanging scenery occurs there too) there is a line which has been called the hanging base (25) below which the escarpment is more or less sheer and above which the scenery hangs. At the south-western end it is over 2,000 feet above the lake, and at the northern end it is about 400 feet above it. A similar line occurs on the western side of Ruwenzori and along the northern section of the eastern side. It is from old E-W (approx.) valleys above this line on the Albert scarp that the short rejuvenated streams mentioned in (*para.* 11) enter the rift by way of falls.

49. The valley is floored by sediments of Tertiary and recent date which in places rise high against the scarps. In the longitudinal embayment produced by the prolongation of Ruwenzori into the rift they reach an altitude of 1,400 feet or more above the water; in the angle formed by the E-W portion of the scarp, west of Hoima, and north-easterly scarp beyond Kaiso they reach 600 feet, and they rise again near the Murchison

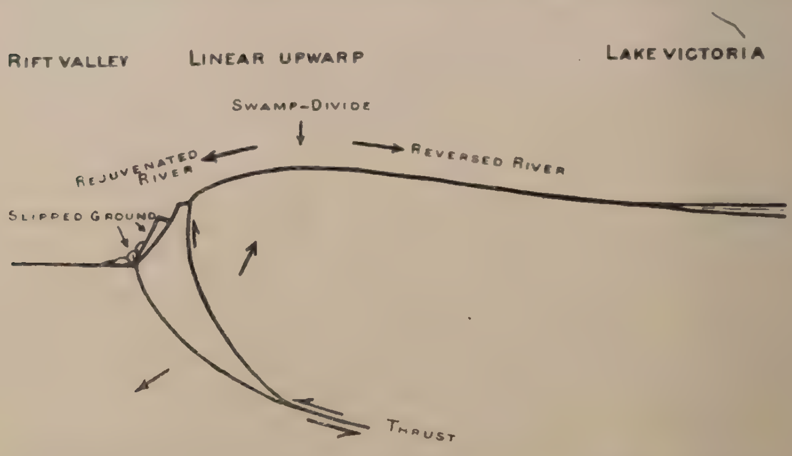

Fig 2. Diagram to illustrate the nature of the Albertine Rift Valley.

falls, where they are about level with the top of the scarp, to about 400 feet. In general these sediments dip towards the lake at low angles but

where the beds are unusually high above the lake they suffer a change of direction of dip near the scarp and turn sharply over towards it; and it is to be noted that these dips (in the Kaiso area for example) although scarpward have a more southerly component than the normal to the line of cliff.

50. In some places the sediments are deformed into dome-like structures. There is one near Butiaba, others on the Kaiso flats, and six have lately been discovered on the Congo side.

51. Gravity faulting occurs locally, mostly behind the scarp, but it is not of the remarkably step-like form which characterises the eastern rift, and has taken place along pre-existing (i.e. pre-rift) fault planes. Some step faulting occurs at the head of the longitudinal embayment to the east of the northern nose of Ruwenzori and to some extent to the east of Lake George on the former at any rate it is below the main scarp. The same is true of part of the western side of Ruwenzori; and there is, one gathers, evidence of collapse in that rare feature a transverse embayment which occurs on the Ngeti area of the Congo.

52. Main faults at or near the base of the scarp that may be taken for primary rift faults or genetically associated fractures are extremely difficult to find, for the reason that they lie concealed beneath lacustrine deposits or talus, masses of slipped material, but SIMMONS (20, p. 14) recorded one, in the West Nile District, which he described as follows:—

"Behind Panyamur is a small gorge cut in the lower escarpment, there is a hot spring, and above it a fault which is probably parallel with the rift fault, is well exposed striking N.E. to S.W. and hading steeply from 85° to the N.W. to vertical."(²)

This fault then plunges down and under the escarpment. When one came to plot this fault on the map it was found to lie right in the line of the western (Congo) scarp (see tectonic map at the end of this volume).

53. Reversed faults occur in the eastern scarp and make features in it. They have long been known to the writer who paid little attention to them however, supposing them to be necessarily pre-rift in age. That supposition, however can no longer be held, for they cross the trends of recognised pre-rift systems, and BAILEY WILLIS has called my attention to a fault which curves upwards in the cliff near Kibero and which is to be interpreted as a thrust rising surfacewards. This fault is a continuation of one previously known.

54. Two series of deposits differing in age and facies have been recorded from the Albertine depression in Uganda.(³) There are the Kisegi

(²) The wording *hading* is a slip; dipping is meant. (E.J.W.).

(³) M. Delpierre, a geologist attached to the Kilo Mines in the Belgian Congo, has studied the geology on the western side of the depression, and has recorded about 2,000 feet of deposits therein. The full thickness of the sediments is unknown for only local bases can be seen.

and Kaiso beds (25), the Kisegi beds being the older. The Kaiso beds are essentially clayey beds with some sandstones, and the Kisegi beds are essentially sandstones with some clays. There appears to be an unconformity between them, but it is probably of local significance only. In the longitudinal embayment between the northern nose of Ruwenzori and the eastern scarp they can be seen dipping north-easterly from an altitude of some 1,400 feet above the lake and the general arrangement of the dips is fan like, that is to say the lower the horizon the steeper the dip, indicating a progressive tilting of the rift block during its depression. A similar feature has been recorded by Dixey (2) in the Nyasa depression.

55. (b) *Work in Bunyoro.* Detailed mapping by Simmons (19), Hirst (9 and 10) and Davies (results as yet unpublished) in Bunyoro have emphasised the existence of pre-rift fault systems including an important N.N.E.—S.S.W. one already referred to (*para.* 25). These investigations cannot be dealt with here, but two points must be noted. Both are from Hirst's work. One is that the Karagwe-Ankolean beds which occur in Bunyoro occupy two longitudinal areas one parallel with the Albertine rift, but separated from it by rocks of the ancient complex, and the other nearly at right angles to this. They were clearly laid down on a subsiding bottom, just as the Kisegi and Kaiso beds that occupy the Albertine depression were, and the suggestion is made that they were deposited in an ancient rift. The second point is stated as follows (10, p. 43):—

"Thus the general tectonics of Bunyoro seem to indicate that the pressures in the area from Pre-Cambrian times onwards have been applied from the south-east, and that the directions along which stresses have been relieved can be resolved into lines having a general N.—S. and E.—W. and N.E.—S.W. orientation, that is lines at roughly 45° and 90° to the indicated direction of pressure." It would seem then that the tectonic activity which gave rise to the rifts in Tertiary times is no new feature.

56. (c) *Ruwenzori.* There are two interpretations of Ruwenzori at the moment, one is that it is completely encompassed by faults and the other is that on the south-eastern side the faults are replaced by flexures.

57. The latter is Willis' view. It may be correct, nothing but detailed mapping will definitely prove or disprove it. Meanwhile it is to be noted that steep scarps are wanting on the east-central and south-east sides the rising ground being approximately delineated by straight lines which are paralleled by fault scarps on the west side of the mountain. One would hardly expect this if the elevation on the east is due to flexure, and a permissible alternative view is that whereas the scarp lines indicate that movement had recently taken place along the faults, the unscarped rises mark places where no movement has taken place along the faults for a relatively long period. If large scale movement along an already existing fault has not exposed the Albertine scarps in late Pleistocene times the

hanging base would not have appeared, and the relationship of the high ground (now above the hanging base) to the low ground—save that it was occupied by water—would have been that of the unscarped parts of Ruwenzori to the plateau of Toro.

58. (d) *The Peneplain.* One of the most significant facts that have emerged from recent work is the recognition of the fact that the dissected plateau evidenced by the flat-topped hills of Uganda is part of the Great African Peneplain, and that it is pre-rift and pre-lake Victoria in age. It renders the distinction between pre- and post-peneplain geology fundamental. It was the disturbance of the long-lasting conditions, that permitted of peneplanation which led to the modern Africa, diversified as we know it to-day in the areas herein considered by great volcanic cones, lava sheets, deep rift valleys and the equatorial lakes.

59. (e) *Lake Victoria and its feeders.* The view (*para.* 30) that the Lake Victoria depression resulted from warping during the early stages of uplift can no longer be held; for one thing, it is clearly younger than the rivers which because they plough through the peneplain are seen to be consequent upon that uplift—and the lake submerges parts of their courses (*para.* 12). The rift valleys, are also younger than the rivers for, as we have seen, the Albert escarpment cuts off the old valleys and leaves them hanging high up on the sides of the rift. The drainage of the rift indeed is at right angles to that of the old rivers which before the rift appeared flowed across its site and doubtless joined the great Congo system, and so fed westwards to the Atlantic.

60. It has been noted (*para.* 12) that Lake Victoria is fringed with drowned valleys which seem to radiate from a centre, and this led the writer to consider the probability of the rivers having risen originally on a dome that once occupied the site of Lake Victoria. This thesis was developed at the International Geological Congress in Pretoria (1929). Since then, however, this matter has been reconsidered, chiefly at the instance of A. D. Combe and Bailey Willis; and the conclusion now arrived at is that it no longer appears necessary to postulate a dome. It is true that the disproof of its part existence is not the simplest of matters, especially so as drainage lines on the eastern side of the lake have been largely controlled by contours determined by lava flows of comparatively late times, but search among records, together with some investigations undertaken in Kenya this year by the writer, render it probable that the Uganda rivers originally rose in Kenya. That they were consequent upon the uplift of Africa may be taken as certain; but there is evidence that the land was higher on the eastern than on the western side of the lake in peneplain times.

62. Woolnough (28) has shewn that given a climate characterised by alternating wet and dry seasons one of the results of extremely advanced peneplanation is the formation of a lateritic ironstone blanket and an underlying leached zone. These conditions are typical of the peneplain

in Uganda, and they exist in a measure in western Kenya, but, so far as the evidence goes, it appears that the oldest lava flows of that country do not ordinarily overlie such a blanket, but rest directly on the ancient crystalline rocks. This is taken to indicate that peneplanation was not so highly advanced in western Kenya as it was in Uganda, so that a watershed existed there, albeit a somewhat otiose one which woke to renewed activity when elevation occurred.

63. It is possible, indeed probable, that the courses of post-peneplain rivers were in large measure determined by wide shallow depressions that marked the channel of effete rivers which, in earlier days, had assisted in the process of peneplanation.

64. We have then, it would seem, this sequence: peneplanation, uplift with the birth of consequent streams, the formation of the Lake Victoria depression and the appearance of the rift valleys as topographical features. The last double event, one would imagine, was responsible for the reversal of the rivers in Uganda, but there exists indisputable evidence to show that this did not take place till long after the rifts first appeared.

64. Lake Victoria is a puzzling feature; on the eastern shores at Karungu (16) and at Rusinga there are thick lacustrine sediments which have yielded a Miocene vertebrate fauna and a molluscan fauna entirely made up of present day species, none of which, however, are now living in the lake (1 and 14).

65. According to Oswald (16) there is, on that side, a lake peneplain, but it yet remains to be proved that it not in reality part of the old peneplain which antedates the lake. On the western side of the lake no such ancient sediments are known. Taking the lake as a whole, its topography together with the marked absence of consequent streams of any importance (on the western side) declares Lake Victoria to be a juvenile feature. There is presumptive evidence that the Victoria depression and the rifts appeared contemporaneously, and in support of that it is to be noted that there are at least 2,000 feet of sediments in the Albert rift and from a low horizon in this series *Dinotherium* remains have lately been claimed.

66. So long as a lake retains its identity as a unit, it cannot of course have more than one outlet for long; yet in the Lake Victoria depression there are gravels that are more than 300 feet above the water on the eastern side and rather less than 300 feet on the western side. These are younger than the river valleys and flank their sides. Are we to believe then that contrary to the natural order of things Lake Victoria has been a central lake with radiating drainage such as Gunther required (8) to account for the distribution of African fishes? Fortunately we are not required to do so, for the gravels are implementiferous, and the fact that they overlie irregular surfaces, and in some places old subsoils, together with other evidence for which space cannot here be found (Handbook) leaves no room for doubt that in Pleistocene times the lakes rose and were united by flooded valleys to form

a vast much branched sheet of water. This was during a pluvial period, and therefore under conditions that might be called exceptional, although relatively long maintained. Nor were the topographic conditions what they are to-day, for a hypsometric map makes it abundantly clear that in no circumstances could 300 feet of water be headed up in Lake Victoria at the present time.

67. This took place before the reversal of the rivers, for gravels doubtless belonging to the Pluvial regime are to be found by Lake Edward at an altitude of about 2,200 feet above that lake, and therefore nearly 1,500 feet above the level of Lake Victoria, while others exist near the Murchison Falls about 400 feet above Lake Albert, and therefore some 1,300 feet below the level of Lake Victoria. Roughly half way between these two, but nearer the former than the latter (to mention but one other occurrence among many) gravels of the same age are found overlying older lake deposits in the lower course of the Muzizi valley, where it emerges from the scarp; they are left stranded above the rift floor at a height of nearly 1,400 feet above the lake, and therefore rather more than 300 feet below the level of Lake Victoria. These differences of level are connected with the movement that exposed the Albert scarps and gave us the hanging base. The south-westerly uprise and the north-easterly downthrow reversed the Kagera, the Katonga, the Ruzizi and the Kafu and turned the Lake Kyoga drainage into the Albert rift by a new channel—the lower Victoria Nile—which in its lower course ploughs its way through the middle Pleistocene beds capped with pluvial gravels.

68. There can have been no large body of water in the Victoria depression except during the Pluvials—for there were two—when all the lakes rose and were joined by flooded valleys. At other times the Victoria depression must have been a swampy area with rivers flowing through it, and no doubt through small lakes in the courses of some of them.

69. The evidence of the Miocene beds on the east and their absence on the west may be taken to indicate the westerly expansion of the basin, *pari passu* with the subsidence of the rift floors and the elevation of their sides; and it is to be noted that the rise of the basin side on the east is much greater and less gradual than on the west.

70. That the rivers were not reversed till this late (mid-Pleistocene or later) movement is further evidenced by the thick accumulation of sediments in the western rift (*para.* 54). These must have been brought in by great rivers which no longer feed into the depression, and the deposits therein that immediately underlie the Pluvial gravels are dated on palaeontological grounds as middle Pleistocene (11). The foregoing then is a very imperfect outline of recent work bearing upon the rift valleys in eastern-Central Africa. Intimately bound up with the history of the rift valleys is that of Lake Victoria and its feeders and it remains to consider the implications of the results of our studies of remarkable features.

VI. The Date of the Rift Valley Faults.

71. There is no reason to believe that the primary rift valley faults, as distinguished from later and from secondary faults or gravity faults, were precisely contemporaneous, though it is not unreasonable to suppose them to be approximately so, and since they disturb the peneplain they must, functionally at any rate, post-date it. Sykes has shewn (*para.* 37) that in Kenya, if nowhere else, they probably antedate the first volcanic outpourings which, if generally true, suggests that they were one of the first consequences of the upward movement of eastern central Africa with its consequent plateau eruptions. They would still be post peneplain; but the fault responsible for the Nandi scarp must surely on Odman's evidence be older. He says that along it the rocks are locally turned to gneisses and it seems impossible that this should have taken place at the surface. Such metamorphism one must suppose took place at depth and therefore before the peneplanation.

72. It has already been mentioned that a north-westerly prolongation of this line would take it into that followed by the Aswa and the north-westerly bend of the Nile below Nimule, and that flinty crush rocks have been recorded along it. It is not suggested that this is one continuous fault, although it may be, but it is suggested that it belongs to the same system of fractures which is known to be one of pre-peneplain age. To this system belongs a crush zone in Kenya which runs south-eastwards from a point south of the Gori river, which discharges into Karungu Bay, through south-western Kavirondo into Tanganyika Territory; along it (in Kavirondo) very ancient porphyries are sheared and metamorphosed into schists, and in it there are auriferous quartz reefs. It would appear therefore that the Nandi scarp has been determined by a very old fracture that, where it veers round to a more meridional direction, was so disposed with reference to the rift forming forces as to be rejuvenated by them.

73. It would seem then that we have primary rift faults formed during an early stage of continental uplift, subsequent and secondary faults, due to gravitational collapse along escarpments and also in consequence of volcanic extrusion, and at any rate one pre-peneplain rejuvenated fault.

74. Rejuvenation of old rift faults is not unknown elsewhere for Wade (21, p. 26) has shewn that in Madagascar the faults of "an Archaean valley, and old rift valley parallel to the rift valleys of Africa" have been rejuvenated in Tertiary times.

75. The geology of Uganda is known to have been cyclic and the possibility of rift valleys of long pre-Tertiary days has already been mentioned (*para.* 55).

76. The deformation accompanying post-peneplain uplift in this part of Africa appears to have been that of a dome the crest of which was in Kenya. It could have been brought about by forces acting entirely vertically,

entirely horizontally or by a combination of both. In any instance there was a vertical component which, sooner or later, must introduce surface stretching and that it did so is evidenced by the plateau eruptions which took place on and near the crest of the dome in Kenya.

77. If the uplift was essentially vertical, stretching, however slight, must have existed from the first, but if it was due to laterally acting forces transmitted at no great depth through the earth's crust the entire dome, so long at it remained low, would be in compression, and only as it was further raised would tension come gradually into play at the surface. Were the doming due to upward relief from very deep seated compression the conditions of surface stretching would have been those of vertical uplift and one has to consider which of these alternatives to adopt.

78. The fact that the pre-rift faults of Bunyoro and elsewhere did not gape may be taken as evidence that stretching in these parts was insufficient to permit of it and therefore insufficient to produce additional (rift) faults, nor does it throw any light on the nature of the forces promoting elevation; but the vast size of the uplift leaves litle room for doubt that the forces that produced it were deep seated.

79. It is difficult to imagine tension in the deep zones of the earth under ordinary conditions, but during a period of melting and expansion, such as JOLY (12) and others have visualised, stretching of the upper layer could occur; but again we have, among other difficulties, that of explaining the stability of the pre-rift faults, and the parallel rift fractures with a depressed block between them. The well known case figured by WEGENER is not true to facts, for according to this an immature rift is a gaping crack filled with tumbled masses from the sides, while a mature rift is occupied by sima. The western rift, at any rate, satisfies neither of these conditions. WEGENER's hypothesis could, with some pleading, be made to account for uplift of the valley sides, but not for the arch-like upswellings which accompany it (*para.* 10), nor for the folded structures within the rift.

80. Moreover, stretching by expansion at depth would be likely to promote fracturing from the base of a continental mass upwards; and supposing this to have occurred and by some unexplained process to have given rise to two parallel fracture which ran to surface, the effect should have been not the foundering of the block between the faults, but its partial extrusion along them as a horst. It is equally difficult to see how deep seated stretching could give rise to continental uplift. Deep seated compression, on the other hand, is free from these difficulties. It would appear then that it is permissible to infer that the uplift was due to deep seated compression.

81. Uplift is probably still proceeding. Seismological investigations undertaken by the Geological Survey of Uganda shew that earth tremors are of extremely common occurrence and that at least one new seismic centre is developing in the western rift valley zone; and in 1928 an earth-

quake occurred in the eastern rift of such intensity as to produce a fracture some fifteen miles in length with a maximum vertical displacement of about 10 feet. There are no measurements to shew whether the movement was entirely upward on one side, entirely downward on the other or differential. It recalls, however, the earthquake of June 17th, 1929, in the Murchison area, New Zealand (5) during which an upthrust fault scarp of 14 feet 9 inches appeared, and it is generally believed that great earthquakes are the result of elastic strain due to compression. Volcanic activity is not entirely extinct. Eruptions occurred in the Lake Kivu district in 1912, and one of the so-called Mufumbro mountains in the Congo is still mildly active. Hot springs occur in the rift valley zone. With regard to Kenya GREGORY says:

"The Western Branch of the Great Rift Valley includes several lofty craters which are in frequent eruption. In B.E.A. the Teleki Volcano was active in 1889, and according to CAVENDISH (1898, p. 390), was blown to pieces in 1896, and a new vent, the Andrews Volcano, was opened 3 miles to the S., Doinyo Ngai, "the mountain of God," which lies a little S. of the British frontier, is apparently often in eruption, as the glow of molten lava in its crater upon the overchanging clouds is often seen at night from the soda works at Lake Magadi. Some of the volcanoes within the Rift Valley in B.E.A. may be only dormant, for they contain active steam vents as well as sulphuruous fumaroles, such as that in the Njorowa Gorge, a little to the W. of which Mr. HOBLEY found a bare volcanic cone that he estimates as not more than 100 years old."

82. The foregoing discussion has shewn that rejuvenated and new born streams were consequent upon early uplift, and that they antedate the appearance of the rift valleys and the Victoria basin. Further, the rift valleys appear to precede in time the first eruptions, and we have seen that there has been uplift since the formation of the rift valleys. Here we meet difficulty. Rift valleys like plateau eruptions appear in a characteristic setting, namely that of uplifted areas, but if the fractures that bound the valleys are a consequence of the compression that elevated the plateau they should have appeared at the time of maximum compression, that is to say immediately before and not after the initial rise; and they should have started from very great depth.

83. From the evidence before then it would appear that deep seated compression is not the immediate cause of rift valleys, and we must look for another. In these circumstances one would welcome the Keystone theory, were it not that there are insuperable objections to it, for there are not only those already mentioned; but EVANS (4), himself a tensionist, has shewn that stretching on the surface of a dome would not give rise to great faults and WILLIS (27) has shewn the Keystone hypothesis is mechanically unsound.

84. The position is then that continued vertical uplift will not explain appearance of the rifts, and that tension must go by the board. What is

the testimony of the Albertine area where the evidence is not obscured by lava flows?

85. There are opposing scarps, which for great distances are parallel and straight, recalling fracture planes (along which movement takes place) which have been many times produced by engineers when testing the strength of materials (Fig. 1). The only known faults that can be claimed as primary fractures in the line of the scarp dip away from the axis of the rift (*paras.* 52 *and* 53). There are thrust faults curving steeply upwards in the Albertine scarp making features in it. There are domes on the floor of the rift, and overturned dips towards the escarpment, almost sitting in the rift is the great upthrust, perhaps partly upwarped mass of Ruwenzori, and there is the uplifted country to the south-west. Added to this are the linear bulges upon which the swamp divides are situated. These facts point to one conclusion: the rift is essentially a compressional feature.

86. During the discussion on rift valleys at a meeting of Section VI. of the International Geological Congress in Pretoria (1929) TEALE, who did not commit himself to any general interpretation of rift valleys, gave an account of overthrust of late date, and a pinched out mountain in connection with the Tanganyika depression; while BAILEY WILLIS, commenting on this, and dealing with his own investigations in the Rukwa area made out a case for radial thrusting, from the vicinity of Lake Victoria. From that evidence, which will doubtless be published later, and from the disposition of the rifts in relation to the eastern coast of Africa, it would appear that Lake Victoria and the Indian Ocean overlie dynamic centres which were the source of the activities that led to the formation of the rift and their associated volcanism.

87. No attempt will here be made further to develop this view, for it is not one for which I was originally responsible and it is anticipated that the question of the origin of the forces which must be invoked to explain the rift valleys will be handled, in masterly fashion no doubt, by BAILEY WILLIS in a forthcoming book. With regard to volcanism, however, a fact of possible significance may be noted.

88. The several lava flows of Tertiary date that appear immediately to the east of Lake Victoria are not the only evidence of volcanicity in that area. It has been said that the geological history of eastern-central Africa as worked out in Uganda is cyclic. The Basement Complex is largely comprised of extremely metamorphosed sediments which must have been of great thickness. They may or may not have been marine. The Karagwe-Ankolean consists of more than twenty thousand feet of beds that were almost certainly laid down in an inland basin and between the two groups is an unconformity representing no doubt a long period of erosion, locally there are ancient sediments that more or less bridge the time gap between the Karagwe-Ankolean and the Complex. The Basement rocks were intruded by granites and their associated apophyses, etc., before Karagwe Ankolean beds were laid down and they in their turn were intruded by

(newer) granite and the whole eventually eroded. Then the Bukoba and other sandstones were deposited in inland basins, and in their turn subjected to denudation. The same may be said of the Karroo; and the last recorded great erosion phase gave us the peneplain which appears to have been initially disturbed in Uganda and Kenya during late Cretaceous times. Granites, and other plutonic products, of post-Bukoba age are unknown, but it is otherwise with less deep seated igneous rocks, and these except for the Mufumbiro volcanics, the ejectima of Toro and Mt. Elgon are characteristically confined to the east of Lake Victoria.

89. Strikingly interstratified with more acid rocks in Kavirondo are hornblende schists and amphibolites that may represent volcanic material of Basement Complex age; and of pre-Karagwe-Ankolean date there are rocks which appear to be altered andesites. There are porphyries of post-Karagwe-Ankolean-pre-Bukoba age, and quartz porphyries probably belonging to this period. Other volcanic rocks appear to be interbedded with Bukoba (Kisii) sandstones which, in this area, are separated from the underlying rocks by a great doleritic intrusion probably belonging to Karroo times. Then comes the Tertiary volcanic succession. It would thus appear that magma reservoirs have come into existence somewhere in this vicinity—perhaps beneath the site of Lake Victoria—on five or six occasions in geological history. The latest of these, if not the others, was probably an indirect consequence of uplift, and has functioned, it would seem as a dynamic centre.

VII. Summary of Events.

90. The sequence of events especially pertinent to the foregoing discussion appears to be as follows:—

(1) Peneplanation.

(2) Vertical uplift of the peneplain, resulting from deep seated compression, with the appearance of consequent drainage from a watershed in Kenya which was rejuvenated by elevation. The westerly flowing streams which rose on this watershed ran across the site afterwards occupied by the western rift in Uganda and joined the Congo flowage to the Atlantic. Associated with the uplift plateau eruptions appeared in Kenya. It is not yet proved, however, whether they were pre- or post-rift. It is probable that they were post-rift in Kenya and it is possible that the Uganda section of the western rift originated somewhat later.

(3) The appearance of the Uganda section of the western rift, no doubt as a minor topographical feature at first, and of the eastern rift in Kenya if it did not come into being somewhat earlier. About this

time the Lake Victoria depression began to make its unimpressive first appearance; and at least one pre-peneplain fault (that responsible for the Nandi scarp), being suitably disposed with regard to the forces then operating, was rejuvenated.

(4) As the Victoria depression and the western rift were gradually emphasised the strongly flowing streams from Kenya crossed the growing depression and cut their courses through the rising and upbulging sides of the western rift. The rift was a compressional feature, and the upbulged sides of the rift resulted from pressure consequent upon resistance of the rift block to depression (Fig. 2). The block was nevertheless forced to sink and the sides to rise. The new gradient, thus introduced, resulted in the drowning of certain valleys of which Lake Kyoga is an example. The discharge from this drowned system was maintained in a westerly direction by the Kafu.

(5) Compression which, from the time when the rift valleys first appeared, caused Ruwenzori to rise and opened pre-existing faults that were orientated normally to the zone of pressure, and which abutted against the rising mass. The extrusion of the Toro volcanics were the result. They did not appear till late in the history of this area. Volcanic extrusion took place on the high land of the south-west and collapse took place giving rise to the big transverse embayment in which the Mufumbiro mountains—most of which are a later expression of this volcanicity—are now to be seen. Eruptions and consequent collapse continued in Kenya throughout.

(6) In the pluvial periods the Victoria depression, the river valleys and the rifts were flooded to form one great branching lake; and during the second Pluvial (Handbook) there came a great movement, the effect of which in Uganda was a marked uprise in the south-west and a relative downthrow in the north-east of the rift valley zone. An effect of this movement was the exposure of the rift scarp of Lake Albert, which up to this time had been buried by sediments slowly accumulating on the relatively subsiding (depressed) rift floor. In conformity with the general movement the greatest exposure of the scarp was in the south-west, and the appearance of the hanging base with its north-easterly dip. This movement reversed the rivers and gave us Lake Victoria much as we know it to-day. A new outlet to Lake Kyoga was similarly brought about by the appearance of the lower Victoria Nile.

(7) Movement is still slowly continuing.

The above is the merest outline and leaves many important matters unmentioned.

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NOTE.

In a relatively little known area like eastern central Africa one's views on even major geological questions must, at this stage, be somewhat in a state of flux; and as this paper goes to press it becomes necessary to announce another discovery. It is this: there is not one peneplain in Uganda but two, one above the other. This is very well seen from the spot where I am now camped in the Mbarara district, and the fact calls to mind other instances of the same thing noted from time to time in different parts of the Protectorate, and that Oswald has recorded a similar phenomenon on the eastern side of Lake Victoria.

The major and older plain is of course the higher one; both must antedate the Victorian depression, and it is suggested that since the lower peneplain must have resulted from the disturbance of the first, that disturbance is probably to be correlated with the first uplift and with the Kapitian outpourings of Kenya (and probably the first eruptions of Mt. Elgon) in late Cretaceous of early Tertiary times. The formation of the lower peneplain indicates another period of rest, during Eocene and Oligocene times, prior to the movements that, as explained in the foregoing pages, finally gave us the present topography.

37. GEOMORPHOLOGIC ASPECTS OF RIFT VALLEYS.

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In his field work the geologist is confronted by topographic forms which are merely the end product of a certain geological history. Every geologist makes use of these forms, to greater or less extent, in deciphering past events. Unfortunately, different geological histories give end products resembling each other so closely that the most conscientious observer is in danger of misinterpreting the record. For this reason it is important that investigators make conscious effort to visualize all possible combinations of events capable of producing similar topographic forms. Only thus will he seek, and haply find, those minor but critically important differences in form or structure which give invaluable clues to the true history of a region.

The foregoing generalizations, which form the basis of what CHAMBERLIN has well called the method of multiple working hypotheses, apply with peculiar force to the results of fracturing and faulting of the earth's crust. The object of this paper is not to present a complete discussion of fault forms, nor to describe the criteria by which the different histories of similar forms may be discriminated; it is merely to emphasize the variety of events possibly responsible for forms which are, or which may be, classed as rift valleys. Since such valleys are, according to the most restricted definition of the term, the direct result of faulting, and consequently involve, among other things the interpretation of such apparently simple forms as scarps developed along fault planes, it will be profitable to begin our discussion with a review of some well established principles relating to these forms.

A fault scarp, in the generally accepted sense of that term, is a line of cliffs or an escarpment directly due to faulting. (Fig. 1). Typically it shows marked indifference to previously established drainage lines, and may be notched by a special variety of hanging valley, these latter being quite as likely to drain away from the scarp fault into the block, as toward the scarp, since they are merely remnants of the pre-fault valley system. Ponded drainage and deflected streams are normal features where the fault-

ing is of recent date. An excellent illustration of a fault scarp, notched by a hanging valley which drains from the scarp into the upraised block, is found on the eastern side of the Klamath rift basin in Southern Oregon. The drainage formerly passing through the hanging valley was deflected south when relative uplift of the block placed the scarp as a barrier athwart its course. Ponded drainage is found in Parowan Valley, Utah, where a stream apparently flowing directly across a small rift valley and long able to maintain its antecedent course despite continued relative uplift of one of the bounding blocks, has recently been partially obstructed by further uplift.

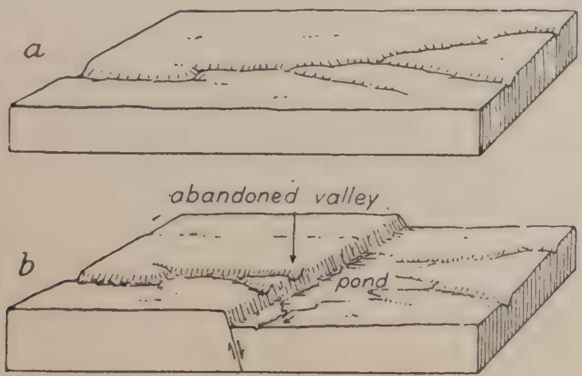

Fig. 1.

A fault scarp may in time be worn far back from the fracture which gave birth to it, and its formerly smooth face may be deeply dissected by stream erosion; yet it is a true fault scarp, young, mature or old according to the stage of its dissection; because it was originated directly by faulting. On the other hand a smooth undissected scarp, coinciding exactly with a fault plane, and having the same stratigraphic horizon at summit and base, clearly marking the precise amount of displacement, frequently is an erosion feature and in no sense a true fault scarp. In the third diagram of Figure 2 we have an escarpment developed along a fault, which might quite naturally be mistaken for a fault scarp due to comparatively recent displacement of the rock; yet the history of this form is more complex. An ancient displacement, possibly dating far back in geological time, produced a true fault cliff shown in the upper diagram. Long continued erosion reduced the country to a peneplane, and the fault scarp was completely obliterated, as shown in the second diagram. In a new cycle of erosion weak rocks were stripped away from one side of the fault plane, giving an escarpment due wholly to recent erosion limited by a fracture of very ancient date. For such a form DAVIS has suggested the name "fault-line scarp." The term has been criticised because it might equally well

signify a true fault scarp, which likewise borders a fault line. "Fault-line erosion scarp" is less concise, but also less open to misinterpretation. In whatever manner we designate this form, we must not confuse it with the resurrected fault scarp, which has had a still different history. In the case of the fault-line erosion scarp there has been no burial of a pre-existing scarp, and hence there can be no resurrection. The only pre-existing scarp (a true fault scarp) was annihilated. The present scarp was not a scarp at all until erosion of weak rocks first gave birth to it.

The distinction between fault scarp and fault-line erosion scarp is no mere matter of academic interest; it is the indispensable prerequisite to a correct interpretation of geologic history. In the Colorado plateau province of America are magnificent escarpments scores or even hundreds of miles in length, and hundreds or even thousands of feet high. The same limestone capping the uplifted block is normally found at the foot of the scarp covering the down dropped block. The scarps are little dissected, and are located directly on the fault planes. Hence DUTTON in his classic "Tertiary History of the Grand Canyon District," described them as young fault scarps, assigned them a date later that the great peneplanation of the area, and interpreted the Colorado River as an antecedent stream which had persisted in its course while the fault blocks were raised across its path. More recent studies by DAVIS and others have demonstrated that the escarpments are for the most part faultline erosion scarps, that the faults are very ancient instead of recent, that they antedated the period of peneplanation instead of following it, and that the Colorado River was probably superposed from the peneplane instead of being antecedent to the still earlier faulting. Failure to recognise the distinction between fault-line erosion scarps and fault scarps inevitably led so able an investigator as DUTTON to give an erroneous chonology for some of the major events in the geologic history of the region, and caused him to overlook phenomena of critical significance which he otherwise certainly would have looked for, and most probably would have found.

If one examines the third diagram of Figure 2 it will be seen that the scarp faces toward the down dropped block, and therefore in this respect gives a repetition of the earlier topography consequent upon the initial faulting. Such a scarp has been called a reconsequent or *resequent fault-line scarp*, to distinguish it from the scarp which would result if the rocks capping the down thrown block had been the more resistant. In the latter case, removal of relatively weaker material from the raised block would give a scarp facing backward, or opposite to the direction which was consequent on the initial faulting. Such an opposite-consequent, or (in briefer form) *obsequent fault-line scarp*, must carefully be discriminated from true fault scarps caused by recent reversal of the direction of movement along an earlier fault plane. The terms "resequent" and "obsequent" easily suggest re-following the initial orientation, and following an opposite orien-

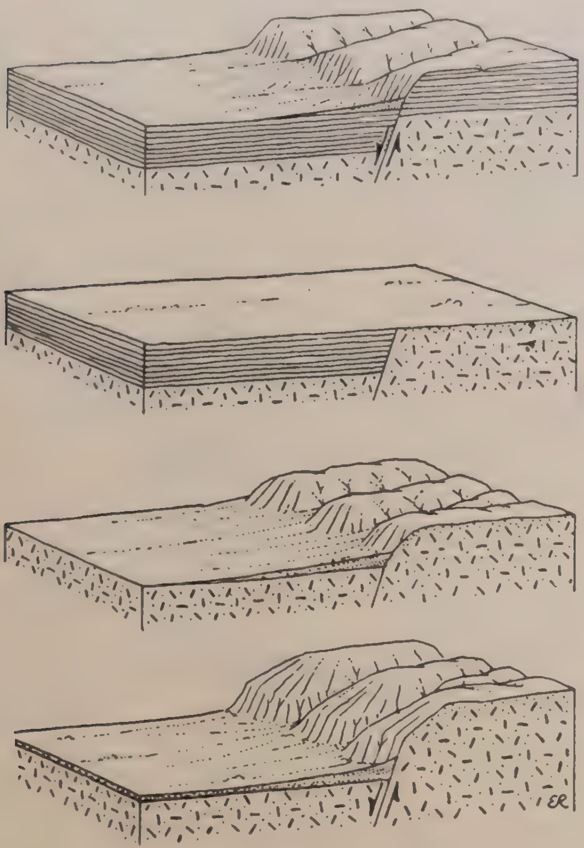

Fig. 2.

tation; and I have found both Davis's discrimination of the two types of fault-line erosion scarp, and his terminology, most helpful in regions like the Colorado plateau where both types are present. It is worth noting, also, that when studying the shorelines of the New England and Arcadian regions, where fault scarp shores have been reported in large numbers, I found not a single true fault scarp, although fault-line erosion scarps are fairly abundant.

The fourth diagram of Figure 2 shows that renewed faulting has given a scarp of double slope, the base of the scarp being steeper, the upper part more gently inclined. In this case it is evident that the upper portion is a fault-line scarp due to erosion, while the lower part is a fault scarp due directly to movement along the fracture plane. An excellent example of such a composite scarp is found in that part of the Hurricane Ledge just south of the Virgin River in Arizona.

Figure 3 shows a similar topographic form, but the history responsible for it is just the reverse. Here the upper part of the scarp is a true fault scarp, as can be seen from the first and second diagrams; while the

base is a fault-line erosion scarp, caused by later removal of weaker beds, some remnants of which remain in places to tell the story. Similar double scarps also occur where a true fault scarp has experienced two periods of uplift separated by an interval of erosion; or where stripping of weak beds to give a fault-line erosion scarp has occurred in two successive cycles; or where the upper beds in either fault scarp or fault-line erosion scarp weather more readily than those below.

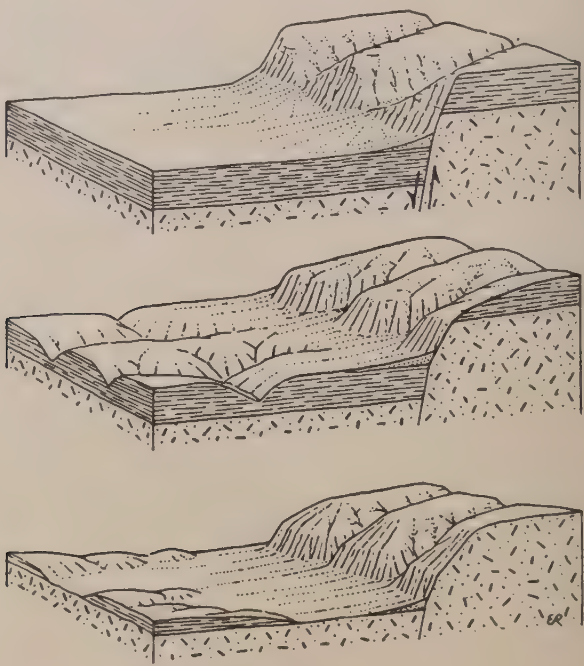

Fig. 3.

Both fault scarps and fault-line erosion scarps may be more or less completely buried by accumulating alluvial or other debris. If alluvium washed from the uplifted block shown in the first diagram of Figure 4 ultimately spreads across the fault plane into the valleys of that same block as shown in the second diagram, the remnants of the scarp still rising above the alluvial accumulation will appear irregular or ragged, with embayments of the sloping piedmont plain between projecting spurs of the upland. Now let renewed erosion strip away the alluvium, and we shall have a resurrected fault scarp, or a resurrected fault-line erosion scarp as the case may be. A key to the true history will sometimes be found in teraces or benches of alluvium high up on the valley walls, as shown in the third diagram. If the alluvium is more completely removed, the true history may only be deciphered with the aid of more remote data bearing on the sequence of events in the region as a whole.

The Central Plateau of France, recently described most admirably by BAULING, furnishes many examples of resurrected fault scarps, and possibly also of resurrected fault-line erosion scarps. The impressive escarpment west of Clermont-Ferrand is a beautiful illustration of the resurrected fault scarp. In this particular case the scarp was first buried by Tertiary alluvium (Fig. 5a), after which one of the Auvergne volcanos poured out a stream of lava which flowed down the alluvial slope and far across the buried fault scarp (b). Later erosion removed much of the alluvium, but the hard lava cap preserved a portion of it (c) in such manner as to form an easy key to the past history. This classic example might therefore be taken as the type of resurrected fault scarps. In the south-western United States a lava flow has similarly preserved such a key to the past history of a part of the Hurricane Ledge which is a fault-line erosion scarp.

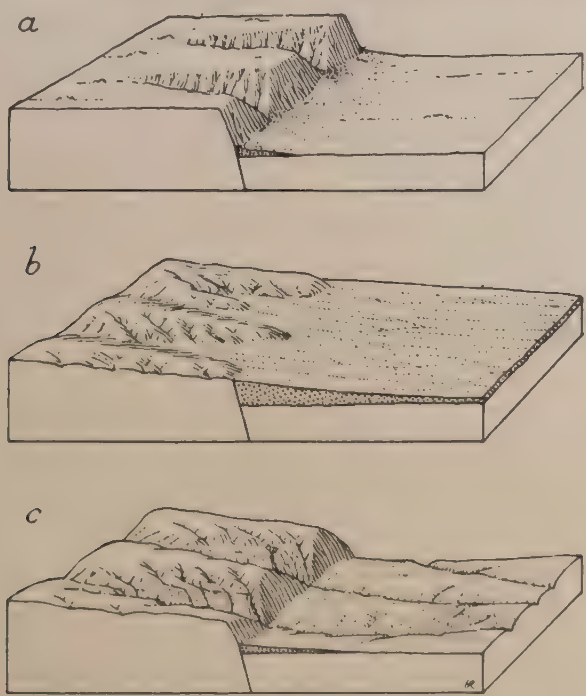

Fig. 4.

Renewal of faulting during the accumulation of alluvium on the down dropped block appears to be a rather common occurrence. This may give a compound scarp in which the upper part is a peculiar type of resurrected fault scarp, the lower part an ordinary fault-line erosion scarp. It will be seen from Figure 6 that a true fault scarp (a) is buried as in (b), after which the buried scarp is again exposed to view, not by erosion as in cases previously considered, but by a renewal of the faulting, as shown in diagram (c.) Further accumulation of alluvium again buries the scarp

(d.) Then the renewed uplift indicated by the arrow in (e) resurrects the upper portion of the scarp "a," while stripping away of the alluvium for the first time gives a fault-line erosion scarp at the base, "b." Assuredly the history is complicated, and one is tempted to say that these minor episodes have only theoretical interest for those who have time to waste on geological cross-word puzzles. To this it must be answered that the history outlined is the normal, expectable history of a growing fault; that the succession of events in nature is ordinarily longer and more complicated than those sketched here; that the resurrected portion of the scarp at intervals contributes debris of its rocks to the alluvium during periods when the future fault-line erosion scarp does not; and that there is thus preserved in the alluvium a decipherable record of past events which may have produced important changes in the topography and in the stratigraphy of regions extending far beyond the limits of the fault zone. The scarp west of Clermont-Ferrand, already cited, may belong to this complex type of resurrected fault scarp. For a long period of time the history of the Connecticut Valley in New England has been misinterpreted because critical evidence of successive movements along the boundary fault on its eastern side was not sought for and hence not found. Only recently have special studies been directed to this phase of the problem, and evidence of repeated faulting found in debris washed into the fault basin from cliffs exposed to weathering in Triassic times. Existing difference of opinion as to the history of this great fracture will doubtless be reconciled when the complex record of successive faultings, alluviations and erosions is more fully deciphered.

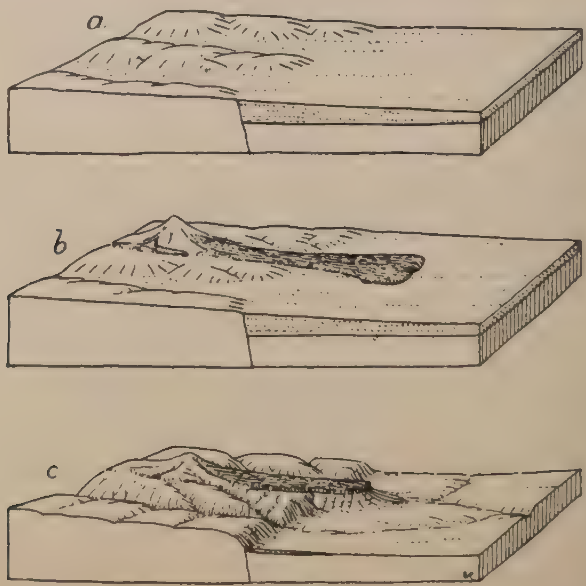

Fig. 5.

Brief reference should be made to the rectilinear valleys which frequently develop along the weakened, sheared zones of single faults or rifts. These have been called fault-line valleys, and their burial by debris and subsequent exhumation would give resurrected fault-line valleys. Examples of both types are known, but as they are not common features along the bounding faults of rift valleys they need not further be considered in the present discussion.

I have taken some time to review the morphological aspects of single fault phenomena because once these are clearly in mind the problems of double and multiple faulting present no special difficulties. The principles reviewed are not new, and one may find references to resequent fault-line scarps, obsequent fault-line scarps, and resurrected scarps in the literature of geomorpholy. There is therefore nothing radical in recognising the morphologic and other differences peculiar to each type, nor in applying them to the discussion of rift valleys and others forms due to multiple faulting.

In treating this latter phase of our subject I shall consider only four major types of blocks included between bounding faults: I. Tilted or monoclinal blocks; II. Rift blocks; or those relatively raised or lowered between normal faults; III. Thrust blocks; those relatively raised or lowered between reverse or thrust faults; and IV. Step block; those raised or lowered progressively between successive faults of concordant displacement. For purposes of this classification I define "normal fault" as any fault which prevailingly hades toward the downthrow; "reverse fault" as any fault which prevailingly hades toward the upthrow.

I. Tilted blocks are the familiar forms commonly described simply as block mountains, or fault block mountains, although this term has also been extended to include horsts which have no obvious monoclina tilting. Tilt block mountains are separated by tilt block basins, the combination being sometimes described as basin and range topography, or basin and range structure. We are concerned here only with such aspects of these forms as may be of significance in connection with rift valleys.

Emphasis has been placed upon the triangular facets separated by V-gorges which frequently characterize the fault face of a tilt block mountain, and it is evident that similar forms may mark the bounding scarps of rift valleys. One point of importance, frequently overlooked in the discussion of tilt block mountains, is that this type of triangular facets and V-gorges indicates continued, progressive displacement along the fault plane in all cases where dissection of the raised block is accompanied by deposition of alluvium on the depressed block. The V-gorges will give place to flat-bottomed valleys as the mounting alluvium enters the gorges and partially buries them. Only when faulting is periodically renewed will the gorges be lifted above the alluvial plain, any accumulated debris

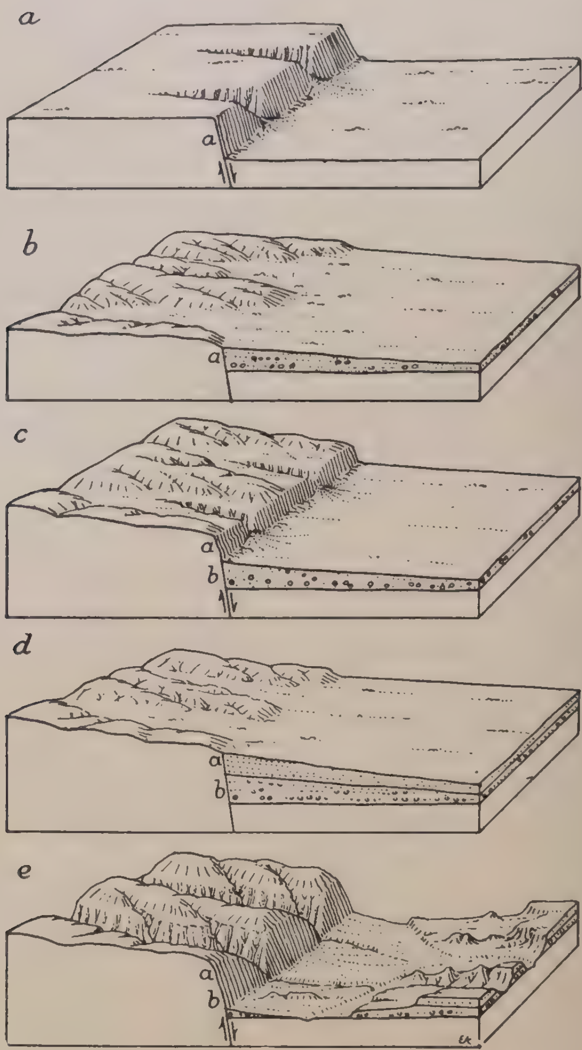

Fig. 6.

be washed out of them, and their V-form restored by renewed erosion. In this way a mountain block, bounding a block basin or a rift valley, may be relatively raised and subjected to re-invigorated erosion many times (Fig. 7), and yet retain a mature topography (although with increasing relief), and equally retain triangular facets separated by V-gorges, as is shown by the classic case of the Wasatch Mountains in Utah, where both maturity of block dissection and youth of facets and gorges are evident.

Differential tilting of a faulted block may be indicated not only by varying height of the fault scarp, but also by various disturbances of the previously established drianage regime. Uplift may even be followed by aggradation of valleys in the raised block; or by aggradation in one part

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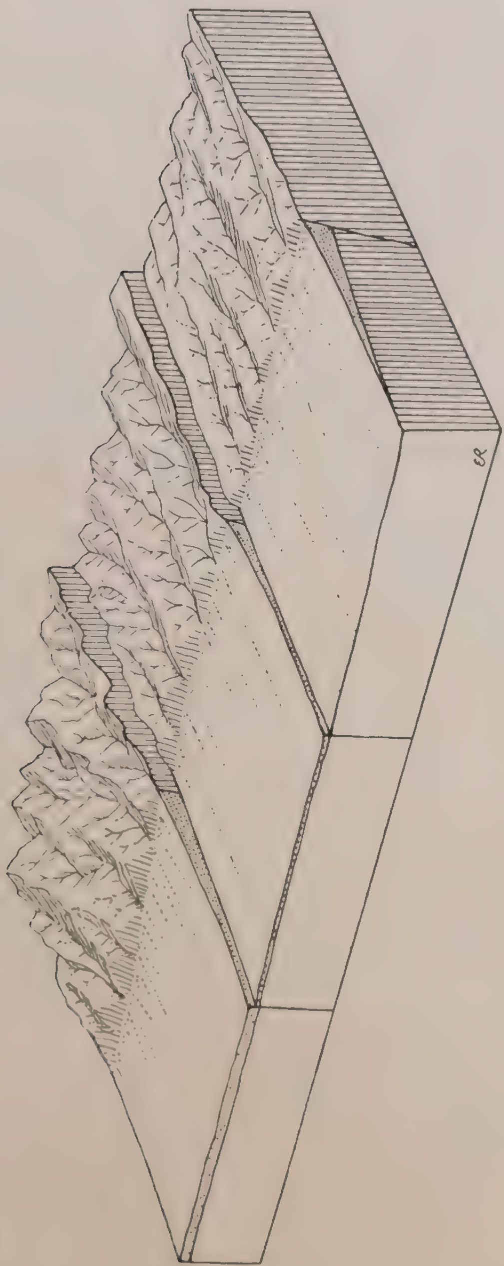

Fig. 7.
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and rejuvenation of erosion in another part of the same block. One such possibility is illustrated in the second diagram of Figure 8, where re-invigorated erosion of the further tributary, which flows with the tilt and is therefore steepened by it, contributes so much debris to the main stream on the depressed block that the latter is aggraded. This aggradation may affect the less uplifted tributary in the foreground of the raised block, especially if the latter flows against the direction of tilt and therefore has its gradient decreased by the differential movement. We may take this as merely one illustration of the kind of drainage disturbances which must be expected in a region of faulting accompanied by tilting, disturbances which will give alluvial deposits on different streams similar in appearance but possibly formed at widely different times and by different tectonic disturbances.

It would not be profitable in the present connection to discuss the varied types of landforms belonging in the tilt block family. But it is perhaps worth while stressing the point that resequent tilt block valleys, that is valleys formed by excavation of infaulted wedges of weak rocks, are of very common occurrence. I have examined several beautiful examples in the Adirondack mountains of New York, while better illustrations have been described from southern Sweden. Such resequent tilt block valleys, as their name implies, reproduce the asymmetrical form due to the earlier faulting, and have therefore in both the localities mentioned been mistaken for original tilt block basins. Obsequent forms, or those involving a renewal of the original topography, are presumably less numerous; while resurrected tilt block basins and resurrected tilt block erosion valleys (both resequent and obsequent) should be included in any complete discussion of this family of land forms.

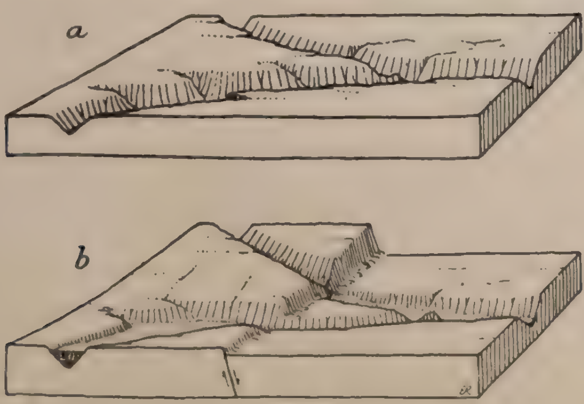

Fig 8

II. We come now to the second group, the rift blocks.—For convenience I include here blocks relatively raised, as well as those relatively dropped, between more or less parallel normal faults. The term rift is

widely used for a single major fracture or fault, without implication as to direction of displacement. Any block between two parallel rifts may thus be termed a rift block, a block separated from adjacent masses by rifts. If the rift block is dropped between normal faults, as shown in the first diagram of Figure 9, we have an original rift block basin, commonly called a graben or rift valley. Since the term rift is employed, as previously noted, for single faults or fault zones like the so-called earthquake rifts; and since true valleys are frequently formed by stream erosion along such single rifts, giving rift valleys which are not grabens; and since, further, we shall have to recognize by some appropriate term a very common type of valley produced when stream erosion excavates a block of weak rocks bounded by parallel normal faults, I should prefer to call the initial form represented by the first diagram a rift block basin, from analogy with the tilt block basins of the basin and range topography of the Western United States; or else to adopt the simple term graben, long naturalized in the English language.

If the erosion which wears back the graben walls, as shown in the second diagram of Figure 9, continues until the country is levelled, the stage will be set for the development of a new form. In case the down dropped block brings weak rock in the centre in contact with more resistant rock on either side, a new cycle of erosion will sweep out the weak rock belt, leaving a broad valley bounded by rectilinear walls coincident with the fault planes. We may even find the same rock capping the bordering uplands and covering the valley floor. In form and structure the new valley may appear precisely like the original basin of the first diagram, and I have not taken the trouble to reproduce it in the series. But its immediate origin is erosional, not tectonic; its history is long and somewhat complicated, not short and simple; and the bounding walls are resequent fault-line scarps, not true fault scarps. The new form might be called a resequent rift block valley.

If, on the other hand, we imagine that the down dropped rift block brought more resistant beds in contact with weaker rocks on either side, as shown in the third diagram (Fig. 9), subsequent erosion will lower the weaker formations and leave the infaulted resistant mass standing in relief. As indicated by the fourth diagram, the resulting form resembles an original rift block mountain or horst; but it is an erosional, not a tectonic feature, and the bounding walls are obsequent fault-line scarps, facing in opposite direction from the original fault scarps. We have here to deal with an obsequent rift block mountain.

It is obvious that if we began the history with a true rift block mountain or horst, and if its uplift brought weak rocks in the centre in contact with resistant rocks on either side, a later erosion cycle would find an erosional rift block valley, bounded by obsequent fault-line scarps, occupying the site of the uplifted block. The Burnet region of Texas is

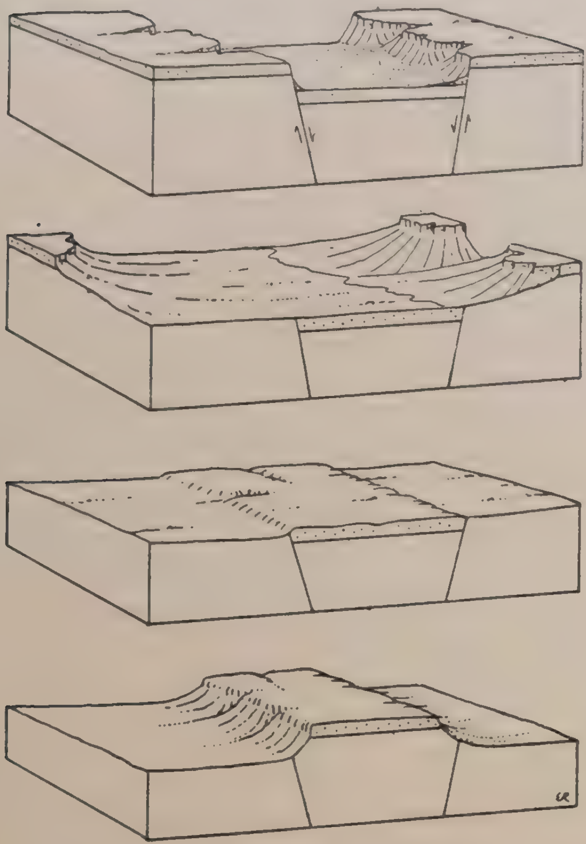

Fig. 9.

described as one in which limestone resting on granite has been so faulted as to give a succession of horsts and grabens. Subsequent erosion destroyed the original topography due to faulting, but left down-dropped blocks of limestone in contact with upraised blocks of granite. In this case the granite proved an easy victim to weathering and erosion in a new cycle, while the limestone was left standing in relief. Thus we have in this region remarkably good examples of both obsequent rift block valleys and obsequent rift block mountains.

Any of these rift block forms may of course be buried and later resurrected. I will cite one beautiful example from the central plateau of France: The Limagne Basin, a resurrected rift block basin where remnants of the alluvial filling, especially were preserved under post-alluvium lava flows, reveal the true history with unusual clarity.

Before leaving the subject of rift block form, I would like to call attention to one feature of original rift block basins worthy of mention. This is the series of fault slivers or splinters which not infrequently characterize the bounding scarps, where the major displacement takes place

not along a single clean-cut fracture, but by means of a series of fractures arranged en echelon. In such a case, as will be apparent from the first diagram of Figure 10, one may start on the down dropped block, ascend the warped surface of one of the fault splinters, and so reach the surface of the raised block without crossing any fracture or fault. If the same number of faults produce the same displacement, but with the faults more oblique to the axis of the basin and hence more widely spaced as in the second diagram, shall we call the resulting form a rift block basin? And if this case passes muster, what shall we say of the third example, where warping of the broadened fault splinters predominates over fracturing to such an extent that a cross section of the basin, as at the front of the diagram, may not show any fault? In the Klamath Lakes Basin in Oregon (Fig. 11), some of the fault splinters are small, while others attain the magnitude of imposing blocks oblique to the axis of the major depression. This basin presents a second problem in that the principal fault bounding the depression on the west has every appearance, when examined in the field, of being much more ancient than the faults on the east. When the fault scarp on the west was fully developed and even badly eroded, there apparently was still no basin. Not until faulting of very recent date occurred was the basin structure completed. Is a relatively depressed block between two faults of widely different ages a graben? Perhaps not; but we should certainly have to include it in the class of rift block basins.

I am tempted to say a word further about this interesting region, because on visiting it in 1915, I found there three phenomena not often encountered by the geologist: true fault scarps of considerable magnitude so young as to be practically untouched by stream erosion; what appears to be the actual fault plane exposed on the face of a range with fault breccia and slickensided surfaces beautifully preserved; and an antecedent stream valley left hanging in the raised eastern block when the rate of uplift exceeded the rate of stream erosion. The latter form is just visible in the northern part of the birdseye view of the basin (Fig. 11) drawn by one of my former students, Dr. Erwin J. Raisz. The fault phenomena were so unusual that I sent my notes to the late G. K. Gilbert, then engaged on a special study of block faulting. Dr. Gilbert later made a detailed examination of the region, from the published results of which is reproduced the cross section of one of the large fault splinters or blocks, cut by the hypothetical trench in the right foreground of Dr. Raisz's drawing.

III. In the family of thrust block forms a central block is bounded by two oppositely inclined surfaces (diverging downward), up which the bounding blocks are pushed or thrust; or the central block may itself be forced downward; or a central block may be pushed first up one, then up the other, of two converging planes. To this family of forms belong the ramp valley of Professor Bailey Willis.

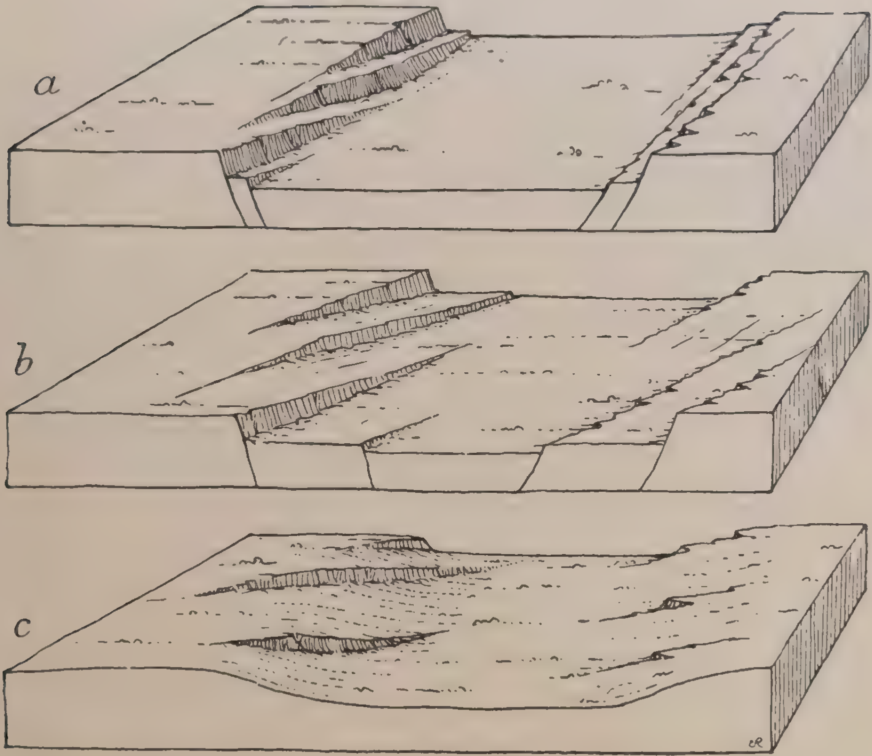

Fig. 10.

Various types of depression may be developed on thrust blocks. It seems desirable to follow the system of nomenclature previously employed, and designate the original depression, produced when the bounding masses are thrust upward and toward each other (Fig. 12), a thrust block basin. After the initial form shown in the first diagram has been softened by weathering and erosion, the base of the scarps may be sharpened and steepened by renewed movement along the thrust planes. Scarps with double or multiple slopes, gravel benches, rock terraces, and rejuvenated valleys may thus in time be observed along the bounding walls.

One peculiar aspect of the thrust walls deserves special consideration. As the mass advances, its forward edge may be unsupported or imperfectly supported on talus or alluvium, with the result that conditions are especially favourable for the development of landslides, shown in the enlargement of a portion of the first diagram in Figure 13. In time weathering and erosion, and deposition of alluvium, will obliterate the slide topography, and the form shown in the second diagram will then be indistinguishable from a weathered and dissected normal fault scarp. Renewed movement will recreate conditions favourable for slipping, and it is conceivable that large landslip blocks, separated by local normal faults, may break from the parent mass thrust forward over imperfectly compacted talus or allu-

vial deposits. Such blocks whether fresh as shown in the third diagram, or weathered as represented in the fourth, might be mistaken for ordinary fault splinters associated with normal block faulting. It is a fair question whether fault splinters and normal fault blocks, as well as slickensided fault surfaces, attributed to rifting of the normal type, may not in some cases at least be the result of large scale landslips on the imperfectly supported front of a thrust block. It seems probable, however, that slipping would occur before any great portion of the thrust block had advanced into an unstable position. For this reason one should expect normal landslide topography, rather than block mountain topography, to characterize the borderlands of thrust block basins. In this connection it should be noted that the diagrams are drawn with the fault planes relatively flat, in order to represent conditions favourable to extensive overthrusting and slipping. In nature we should expect adjacent thrust faults dipping in opposite directions to be more steeply inclined, and hence less favourable to local slipping of broad blocks.

It is hardly necessary to discuss in detail the other members of the thrust block family. A little consideration will suffice to show that we must recognize the possible existence of resurrected thrust block basins, resequent and obsequent thrust block valleys, and resurrected resequent and obsequent block valleys. Thrust block mountains of various types may also exist. Their essential characteristics may readily be deduced from considerations already presented.

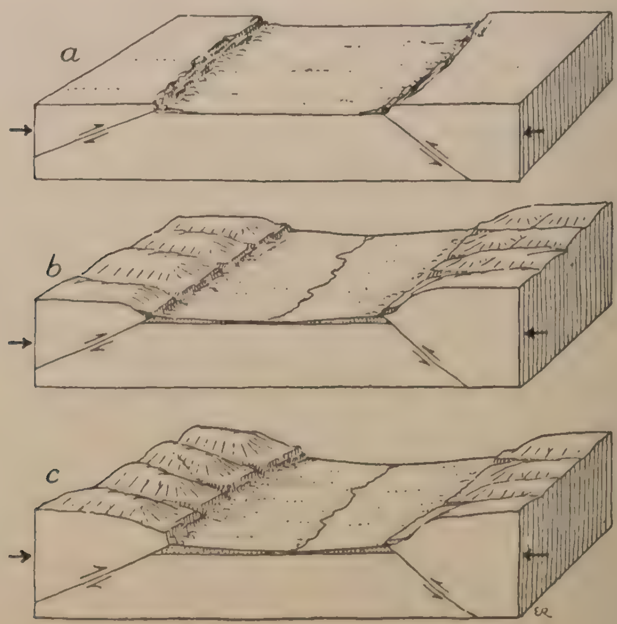

Fig. 12.

IV. It might appear, at first thought, that the fourth group of fault blocks, step blocks, should not concern us, since such blocks, horizontal and each relatively displaced in the same sense, give rise to a series of ascending or descending platforms or steps, but neither to basins nor to mountain blocks. We must remember, however, that both normal and reverse fault blocks may be so displaced that resistant and non-resistant rocks are brought into contact. Later diffential erosion of the faulted mass may then give valleys bounded by parallel rectilinear fault-line scarps, and resembling other forms previously described so closely as to be almost indistinguishable from them. Thus is the case of three step fault blocks, if after peneplanation the central block happens to have exposed at the surface weak shales, let us say, in contact with resistant quartzite on one hand and resistant limestone on the other, erosion in a new cycle will sweep out the shales leaving a step block valley between quartzite and limestone uplands. A little consideration will show that this valley will be bounded on one side by a resequent fault-line scarp, on the other side by an obsequent fault-line scarp. We may therefore speak of this form as a resequent-obsequent step block valley.

Another case is illustrated in the series of diagrams forming Figure 14. A mass is faulted, peneplaned, and further eroded in a new cycle to give an obsequent fault-line scarp, facing in the opposite direction from the scarp consequent on the initial faulting, as may be seen in the third diagram. Now a new block is uplifted, in the same sense and in front of the obsequent scarp. This produces, as the fourth diagram shows, a true fault scarp, consequent on the new faulting, facing toward the other scarp. The depression between may be called an obsequent-consequent step block valley. I use valley in preference to basin, because one wall and the floor are erosion products, even if the remaining wall be a tectonic product. In a similar manner we may have produced resequent-consequent step block valleys.

Repeated movement along a single plane may, with the intervention of normal erosion, give a special type of obsequent-consequent step block valley. The mass is first faulted (Fig. 15), then peneplaned, and through long-continued later erosion the obsequent fault-line scarp is worn far back from the fracture plane, as shown in the third diagram. Then renewed displacement along the original plane and in the original sense, gives a true fault scarp for the opposite boundary of the depression, which might be called a single fracture obsequent-consequent step block valley. The name is long, but self explanatory. The history involved is merely that which we know to have occurred repeatedly in nature, later movement along an old fracture following peneplanation, uplift and renewed erosion.

We need only add that each of these four forms of step block valleys may be buried and resurrected; and then pass to one or two concluding observations.

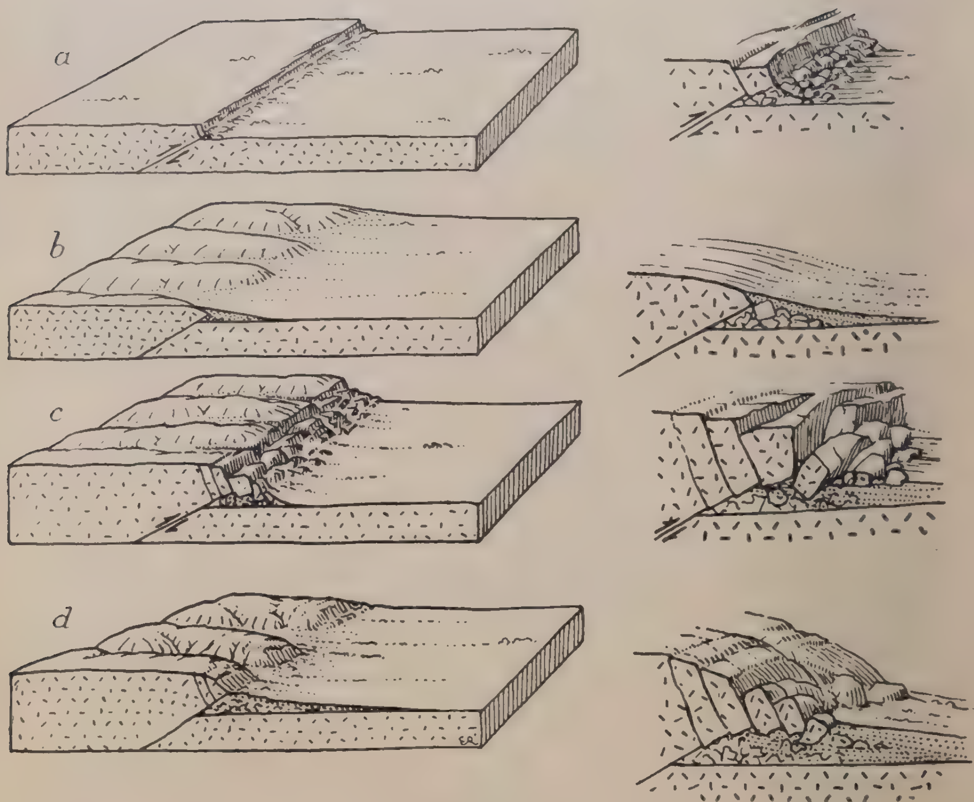

Fig. 13.

My object has been to show that forms sometimes identical in internal structure, and often so similar in outward appearance as to deceive the experienced geologist, may have histories differing widely one from the other. It may be objected that the picture I have painted is too confusing as to terminology, too theoretical as to substance, and too complicated as to successions and combinations of events to be of practical value.

To the first indictment I would make two answers. No less than forty forms (the number would be greater were all types of faulting considered), each having a geological history different in some essential respect from all the others, require to be named. This can be done with the aid of only 12 technical terms, most of them already common property of geological science, and all but one of them found in one or more of our college text books on geology. Fault scarp has been distinguished from fault-line erosion scarp, tectonic basin from erosional valley; rift, thrust, tilt and step blocks have been discriminated; and the consequent, obsequent, resequent and resurrected forms associated with each described. This does not seem to me an unduly elaborate equipment with which to designate in explanatory terms, forty important types of land forms, many of which,

perhaps all of which, occur repeatedly in Nature. Will the mineralogist or the palaeontologist name forty species of minerals or forty species of fossils, with so modest an equipage as 12 terms, most of them previously in common use? Of the terms I have employed, five alone will require even the most moderate effort to understand their significance. Indeed, since rift and thrust are now so well known, I may reduce the number to three: consequent, resequent, obsequent, all of them used in at least one standard textbook of geology for more than a decade, and all suggesting in some measure their own significance. I do not see how a more simple or less confusing terminology *could* be devised to define and at the same time in some measure describe and explain concisely forty distinct landforms.

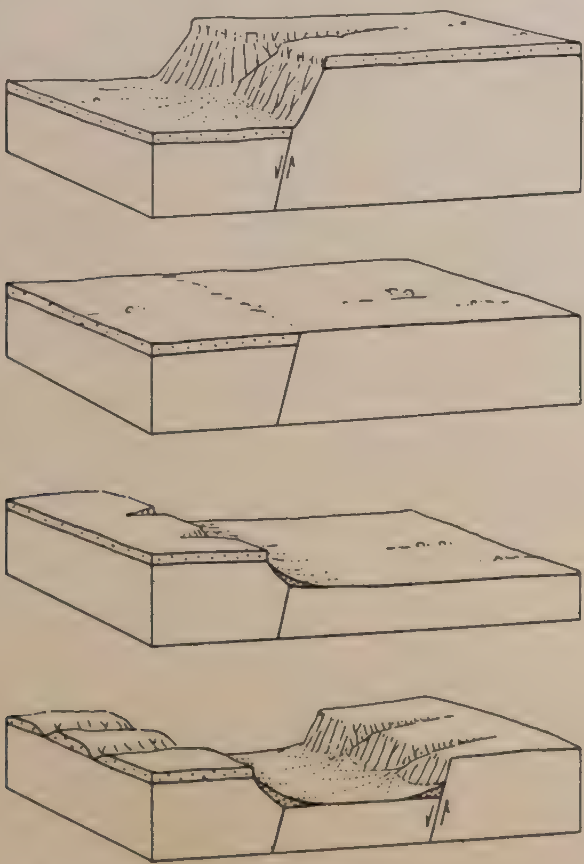

Fig. 14.

But I would not quarrel with anyone who may entertain a contrary opinion. After all, the precise terms to be used are of secondary importance. Our concern is first of all with the landforms themselves, and the geological histories back of them. If anyone can suggest some other

terminology which will more easily keep in the mind of the field investigator of faulted regions the forty or more forms liable to be encountered there, their respective histories, and the means of discriminating them, I will wholeheartedly accept the substitute. If the discrimination between basins as tectonic forms and valleys as stream erosion forms proves unacceptable, because the term valley is often loosely applied to depressions of tectonic origin, then call the basins consequent rift block valleys, consequent thrust block valleys, and so on. Or if the terms consequent, resequent and obsequent confuse rather than clarify things, even for those who have expended the moderate effort required to understand their meaning, then discard them and invent other terms which may prove more acceptable. Any terminology which, after fair trial, fails to simplify and clarify things for the geological investigator, should give place to something better.

That the classification of fault forms outlined above is too theoretical, I can not admit. It is based on relatively simple geological histories, known to have occurred repeatedly in nature. I have given examples of many of the types mentioned, and had time permitted could have added

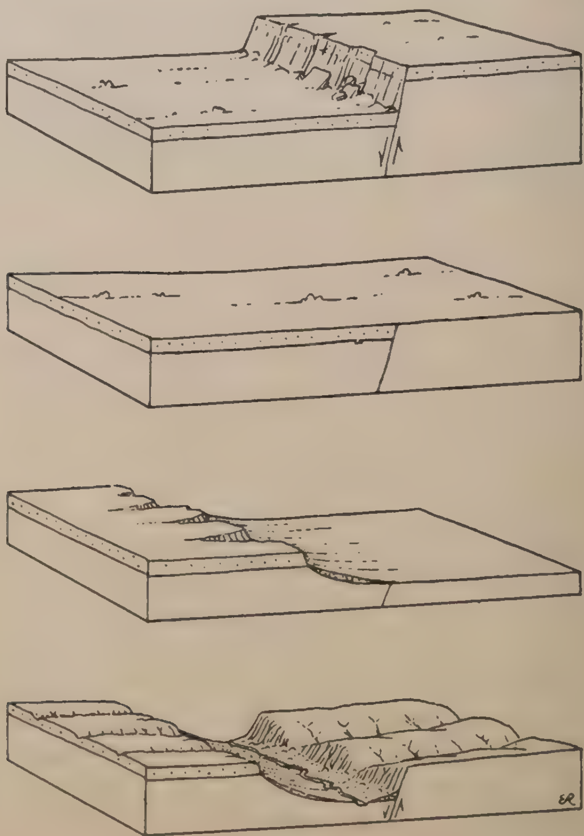

Fig 15.

others. If a few of the types are as yet unreported from the field, it seems to me more reasonable to suppose that this is because of the deficiency of our knowledge, and especially because these forms have not been recognized even when observed, rather than to suppose that they do not exist in all the wealth of fault phenomena exhibited by the uneasy crust of our planet.

Finally, to the charge that the classification of fault forms presented is too complicated as to successions and combinations of events, I would answer that different observers have already reported fault histories more complicated than any I have described. And if nature has faulted, eroded, buried and resurrected blocks of the earth's crust in a great variety of ways, should not the geologist go into the field with a clear mental picture of all the possibilities, and make a conscious effort to find the critical evidence, often preserved in a few obscure localities, which may enable him to read the record aright?

I am, as the reader will observe, urging the importance of deliberately employing in field studies of faulted regions what CHAMBERLIN has called the method of multiple working hypotheses. The rift-valley region of east central Africa has been described as one in which cycles of diastrophism, vulcanism, and erosion have succeeded each other more than once. It is in such regions that fault phenomena are apt to be most complex; and hence I have thought it not impossible that those fortunate enough to work in this remarkable district might find CHAMBERLIN's method useful in directing attention to elements of the topography which, however obscure, possess critical value for deciphering the geological history of faulted and peneplaned masses.

38. TEKTONISCHE EXPERIMENTE UND DIE ENTSTEHUNG VON BRUCHLINIEN. (RIFT VALLEYS.)

VON

H. CLOOS.
(Bonn, Germany.)

(Mit Lichtbildern und Vorführungen.)

(ABSTRACT).

Zur Nachahmung gebirgsbildender Vorgänge eignet sich in besonderer Weise Ton. Seine physik. Constanten (Druckfestigkeit, etc.) sind je nach Verdünnung etwa 50,000 bis 100,000 mal kleiner als diejenigen unserer verbreitetsten Gesteine. Er entspricht also diesen bei einer ebensolchen Verkleinerung des ganzen Gebirges. Mit Wasser fein und dünn angerührt, *fliesst* er und *gibt* selbst in niedrigen Schichten *der Schwere nach.* Gleichzeitig aber liefert der Ton *Scherungs- und Zugrisse* entsprechend den Spannungen, welche durch die Bewegung der Tonmasse in ihrem Innern entstehen. Trotz der Dünnflüssigkeit bleiben diese Risse scharfkantig und ebenflächig und lassen sich genau messen. Übergiesst man den nassen Ton während des Versuches mit Wasser, so überwiegen Zugrisse und Spalten, (weil der kapillare Unterdruck aufgehoben wird.) Ohne Wasser entstehen nur Scherungsrisse. Die Leichtbeweglichkeit des Tones gestattet, ihn fast alle im Grossen auftretenden Bewegungen ausführen zu lassen und Brüche und Falten in ihren Beziehungen zu einander und zur Gesamtbewegung zu untersuchen. Vorgeführt werden Faltung und Deckenschübe, sowie die Bildung von Verwerfungen und Gräben bei horizontalen, schrägen und vertikalen Verschiebungen, sowie bei Zusammenschub und Zerrung.

39. RIFT-VALLEYS (GRABENBRÜCHE) IN MITTELEUROPA.

VON

DR. ING. ERICH SEIDL,
Belin-Westend.

I. Erfahrunggemäss gelten für eine unter mechanischen Gesichtspunkten erfolgende Beurteilung der Entstehung von Gebirgen und anderer geologischen Störungs-Bereiche grundsätzlich analoge Gesichtspunkte wie für die Beurteilung der "bleibenden Formänderung," die Gesteine oder Metalle in der Technik (bzw. bei der Materialprüfung) erleiden.

So habe ich in einer Reihe besonderer Untersuchungen nachweisen können,(1) dass man in der Technik wie in der Geologie aus dem Zustand des Verformungs-Bereichs (geometrische Verhältnisse der äusseren und inneren Form [Massenverteilung]) bestimmte Rückschlüsse auf die Art der Beanspruchung ziehen kann.

II. Die "Grabenbrüche" ("Rift Valleys"), die ich bisher in Mittel-Europa untersucht habe, zeigen im Grundriss und im Querschnitt oft ausgesprochen diejenige Form, welche die Zerreiss-Zonen der Technischen Mechanik haben. Die Fig. 1 zeigt die Seiten-Ansicht einer geschichteten Metallplatte, Fig. 2 einen Querschnitt durch eine einzelne Schicht die in einem Metalldraht zerrissen ist, Fig. 3 Grundniss-Schemata von Zerreiss-Zonen, die (a) durch zweiseitige und (b) durch mehrseitig bis ringsum radial wirkende Zug-Spannungen entstanden sind.

III. Diese Zerreiss-Form kennzeichnet sich folgendermassen:

1) Gesamtkörper.

Die beiden Teilstücke sind jedes für sich länger als das ihnen entsprechende Stück des unversehrten Körpers.

An der Zerreiss-Stelle lassen sich die Teilstücke nicht mehr lückenlos aneinder fügen.

Die Teilstücke zeigen manchmal deutlich beträchtliche Material-Verschiebungen, insbesondere Verjügungen des Querschnitts, die entsprechend einem zuweilen erkennbaren Netz von Kraftwirkungs-Flächen angeordnet sind.

2) Zerreiss-Stelle.

An der Zerreiss-Stelle ist der Körper verjüngt (Grundriss, Längsschnitt); es ist dort gegenüber dem Ausgangs-Zustand nunmehr weniger Masse vorhanden.

Die Oberflächen-Teile des Körpers schliessen sich unter Zurückbleiben der Kernzone—in Richtung auf die Zerreiss-Stelle zusammen.

Mithin liegen an der Zèrreiss-Stelle die Oberflächen-Teile nunmehr einander genähert, während die Masse der Kernzone zurücktritt.

Die Bewegungen die die Mittel-und die Aussen-Schichten im Verhältniss zur Gesamtbewegung der zerrissenen Schicht ausführten, zeigt das Schema Fig. 4.

Bei geologischen Gesteinsschichten, bei denen eine einzelne Schichten-Gruppe zerreisst, zeigt sich (wie beim Zerreissen einzelner Schichten von Metallen), dass plastische Nachbar-Schichten, die sich darunter (oder auch darüber) befinden, in die Zerreiss-Lücke eindringen (Schema, Fig. 5.) [2]

IV. 1.) Die Querschnitte durch das "Obere Allertal" (Fig. 6 a. und b.) seien als Beispiel angeführt für eine verhältnismässig dünne (spröde) Schichten-Gruppe ("Deckgebirge" aus Trias-und Jura-Schichten), die über dem plastischen Salzlager (Perm) zerriss.

Deckgebirge und Salzlager sind durch Tiefbohrungen und unterirdische Baue der Kalisalzbergwerke besonders gut aufgeschlossen.

Diese Zone wurde ursprünglich, als nur die Tages-Aufschlüsse bekannt waren, als Grabenbruch, später, als dass stock-förmig angestaute—Salzlager aufgeschlossen wurde, als "Salzhorst" aufgefasst.

2) Bei den sogenannten "Hessischen Gräben" bildet ebenfalls das Trias-Deckgebirge eine Zerreiss-Zone, in die die (von permischen Schichten gebildeten) Basis-Massen eingedrungen sind.

3) Der Querschnitt durch die bisher als "Grosse Skandinavische Ueberschiebung" bezeichnete Zone (Fig. 7) sei als Beispiel für eine Zerreissung einer "Schild"-Platte über plastischen Basisschichten angeführt.

Die über der zerrissenen Platte liegenden Silur-Schichten sind in die Zerreiss-Zone hinein geglitten, wobei einige Schichten-Gruppen zu "Gneis" umgeformt wurden.

Die unter der zerrissenen Platte auftretenden Caledonischen Gesteins-Massen wurden nach oben in die Zerreiss-Zone hineingepresst.

4) Die bisher als "Kristiania-(Oslo) Graben" bezeichnete Zone ist in geomechanischer Hinsicht meiner Auffassung nach in gleicher Weise gebaut wie die grosse Skandinavische Zerreiss-Zone.

Die bisher erwähnten Zerreiss-Zonen erscheinen bei der Betrachtung im Grundriss als lange, verhältnismässig schmale Spalten, sodass man aus dieser Form nach den Erfahrungen der Technischen Mechanik (Fig. 3a) auf, vornehmlich zweiseitige Zug-Beanspruchungen (Zug und Gegenzug) schliessen kann.

5) Zerreiss-Zonen hingegen die, wie das "Nördlinger Ries" (30 km. Durchmesser) oder das in dessen Bereich auftretende "Steinheimer Becken" (Grundriss, Fig. 8) die Form eines "Lochsterns" haben, (Fig. 3 b) dürften insbesondere nach den Untersuchungen, die ich über lochstern-förmige Zerreiss-Zonen in dünnen Eisdecken ausgeführt habe, durch ringsum radial wirkende Zug-Spannungen entstanden sein. Der Querschnitt durch das Nördlinger Ries, den ich an anderer Stelle veröffentlicht habe,(3) zeigt in den Grundzügen dasselbe Bild wie die Grosse Skandinavische Zerreiss-Zone (Fig. 7.)

V. Die "Afrikanischen Gräben" und die "Zerreiss-Zone des Roten Meeres" konnte ich nicht untersuchen. Doch zeigen einige Grundrisse und Querschnitte die das Schrifttum enthält, die wesentlichen Merkmale der Zerreiss-Form.

Für die Konstruktion der Zonen welche lang gestreckt sind, käme als Analogon in erster Linie die Grosse Skandinavische Zerreiss-Zone und für lochstern-förmige Zonen das Nördlinger Ries in Frage.

Bei der Beurteilung derartiger Zerreiss-Zonen muss man sich über folgendes klar sein:

Eine Zone die noch ganz erhalten ist, erweckt, wenn nur die obersten Schichten aufgeschlossen sind, den Eindruck eines "Grabens" (Schema, Fig. 9, b.) Ist hingegen der obere Teil der Zerreiss-Zone durch Abtragung beseitigt, so ruft der verbliebene untere Teil den Eindruck eines "Horstes" hervor (Schema, Fig. 9, c.)

Findet anschliessend an den Zerreiss-Vorgang noch ein Aufströmen von Magma oder von Salzmasse statt, die etwa die Basis der zerrissenen Schichten-Gruppe oder Platte bilden, dann ergibt sich noch eine Umgestaltung in folgender Weise:

a) die Ausbreitung des Magmas bzw. der Salzmassen zu einer pilzförmig übergreifenden Lagerung.

b) eine Einsenkung der Deckgebirgs-Schichten und die Umgestaltung der Randzone derselben durch das aufströmende Magma oder Salz.

ANMERKUNGEN.

(1) a. Seidl, E., Geologische, durch Zerreissvorgang entstandene Störungszonen als Probleme der angewandten Mechanik; 4 Textbilder; Vortrag.
II. Internationaler Kongress für Technische Mechanik in Zürich 1926. Sonderdrucke Komm.-Verlag Max Weg, Leipzig.

b. Seidl, E., Vergleich technischer und geologischer Biege—bzw. Knick-zonen, insbesondere im Deutschen Kalibergbau-Gebiet; 3 Textbilder; Zeitschr. d.D Geol. Ges., Bd. 80, 1928, Mon.-Ber. Nr. 5. Sonderdrucke Komm.-Verlag Max Weg, Leipzig.

c. Seidl, E., Die Salzstöcke des deutschen (germanischen) und des Alpen-Permsalz-Gebietes; ein allgemein-wissenschaftliches Problem; 2 Karten, 90 Bilder; Z. Kali, 1927, H.3. Sonderdrucke Komm.-Verlag Max Weg, Leipzig.

d. SEIDL, E., "Probleme der Geologie, insbesondere der der Salzlagerstätten, die zugleich Probleme der angewandten Mathematik und Mechanik sind; 3 Textbilder; Z.f. Angewandte Mathematik und Mechanik, Bd. 5, 1925, S. 134. Sonderdrucke Komm.-Verlag Max Weg, Leipzig.

e. SEIDL, E., Ableitung der Knick—bzw. Biege-Form in Technik und Geologie aus ihren Elementen; Anwendung auf den Alpen-Bogen; 28 Bilder, 1 Karte, Gerlands Beiträge zur Geophysik, 1929, Bd. 22, H. 1/2, s. 175-202 Sonderdrucke Komm.-Verlag Max Weg, Leipzig.

f. SEIDL, E., Bruch- und Fliess-Formen der Technischen Mechanik; ihre Anwendung auf Geologie und Bergbau. I Bd. Grundlagen der vergleichenden Betrachtung,, II Bd. Scher-Form, III Bd. Zerreiss-Form, IV Bd. Zerdrück-Form, V Bd. Biege-Knick-Form, VI Bd. Stromungs-Form; je etwa 100 bis 200 Bilder; Verlag des Vereins Deutscher Ingenieure, Berlin, 1929.

(2) SACHS, G., und SEIDL, E. Örtlicher Massenausgleich unter der Wirkung örtlich angreifender Kräfte in Technik und Geologie, 23 Textbilder, Die Naturwissenschaften, Heft 49/50, 1925. Sonderdrucke Komm. Verlag Max Weg, Leipzig.

(3) SEIDL, E. Das Nördlinger Ries, eine Zerreiss-Zone. Z.d.D. Geol. Ges., Herbst 1929. Sonderdrucke Komm. Verlag Max Weg, Leipzig.

Fig. 1. *Zerrissener Flachstab aus geschichtetem Metall;* Kufer—(dunkel) und Blei (hell) Bleche mit einander verlötet. (Vers.: M. Rudeloff; Aufn.: E. Seidl). Kennzeichnende Zerreiss-Form des ganzen Stabes und der Blei-Teilbleche; sprödes Verhalten des Kupfer-Teilblechs.

Fig. 2. *Aluminium-Draht mit Fliess-Schichtung; eine einzelne Schicht beim Drahtziehen aufgerissen.* Einschmiegung der unter Druck- und Fliess-Spannungen stehenden Nachbarschichten in die Zerreiss-Zone. (Aufn.: H. Bohner, Z.f.Met. 1928, S.312, Abb. 12.)

Fig. 3. *Grundrisse von Zerreiss-Zonen.*
a) bei zweiseitigen Zug; b) bei mehrseitig bis ringsum radial wirkenden Zug.

Fig. 4. *Schema der Bewegungen.*
des gesamten Objekts und seiner mittleren Schichten und relativ der Oberflächen-Schichten.

Fig. 5. *Schema des-Verhaltens-einzelner Schichten einer Schichtengruppe.*
Eine spröde Bank (sp) zerrisen. Einschmiegung der bildsameren Nachbar-Schlichten (pl) in die Zerreiss-Zone unter mehrseitigem Druck.

Fig. 6. *Zone des Oberen Allertals (Mitteldeutschland, Aufgefasst als Zerreiss-Zone.*
Zerreissung der spröderen Deckgebirgs-Schichten (Kalk-, Ton- und Sandstein-Schichten) und Einschmiegung der bildsameren Basisschichten des (permischen) Salzlagers in die Zerreiss-Zone. (Konstr. des Deckgebirges nach A. Mestwerdt und Th. Schmierer; Bergbau-Aufschl. des Salzlagers: E. Seidl). Die Querschnitte a) und b) haben einen Abstand von etwa 40 Km. von einander.

Fig. 7. *"Grosse Skandinavische Störungs-zone," aufgefasst als- Zerreiss-Zone.*
Querschnitt, Konstruirt nach dem von W. C. Brögger und V. M. Goldschmidt veröffentlichten Querschnitt.

Fig. 8. *Steinheimer Becken im Riesgebiet (Süd-deutschland), aufgefasst als Zerreiss-Zone.*
Grundriss, veröffentlicht von W. Branca und E. Fraas, 1905.

Fig. 9. *Auffassungs-Möglichkeiten von Zerreiss-Zonen.*
a) ganze zone, b) oberer Teil aufgeschlossen, scheinbarer "Grabenbruch." c) unterer Teil aufgeschlossen, scheinbarer "Horst."

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Fig. 1.

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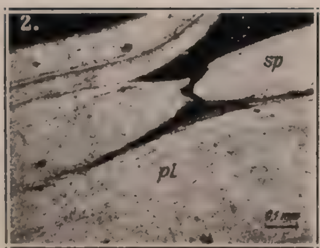

Fig. 2.

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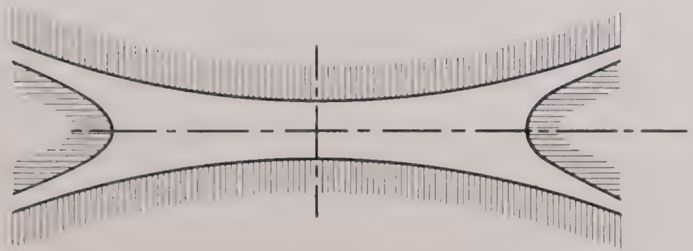

Fig. 3a.

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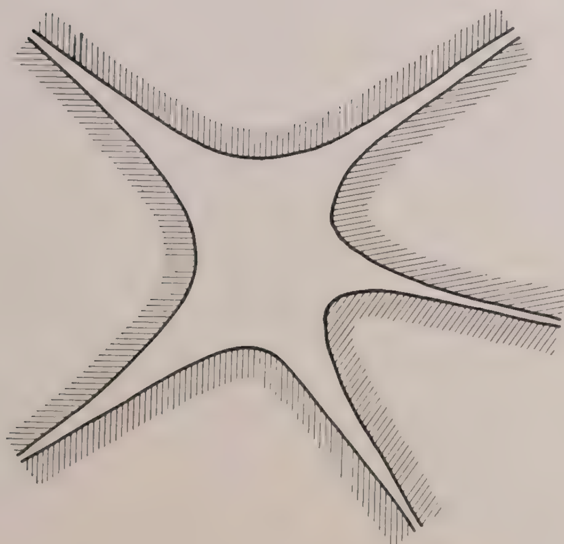

Fig. 3b.

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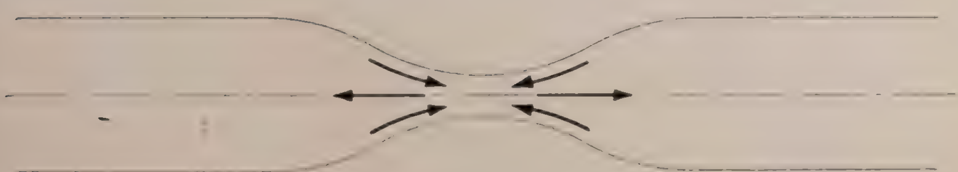

Fig. 4.

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Fig. 5.

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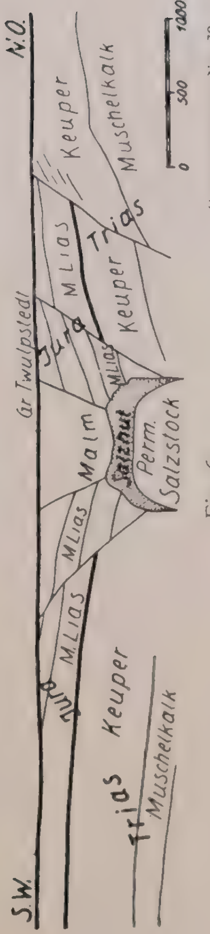

Fig. 6a.

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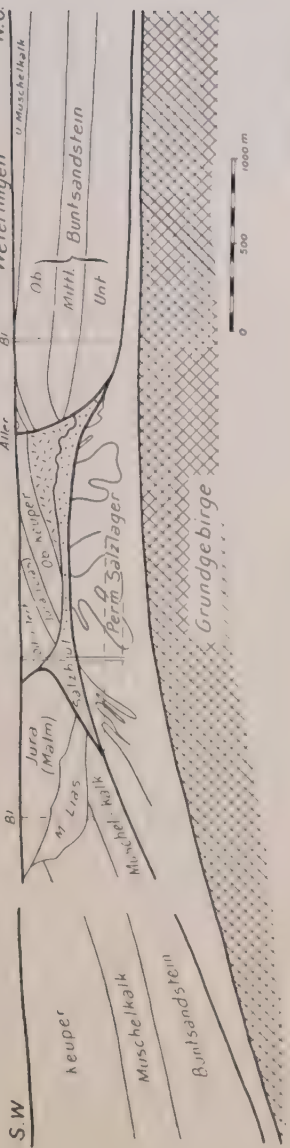

Fig. 6b.

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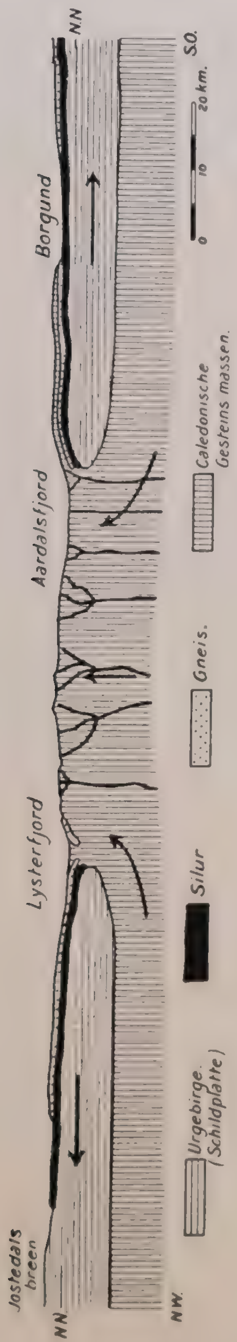

Fig. 7.

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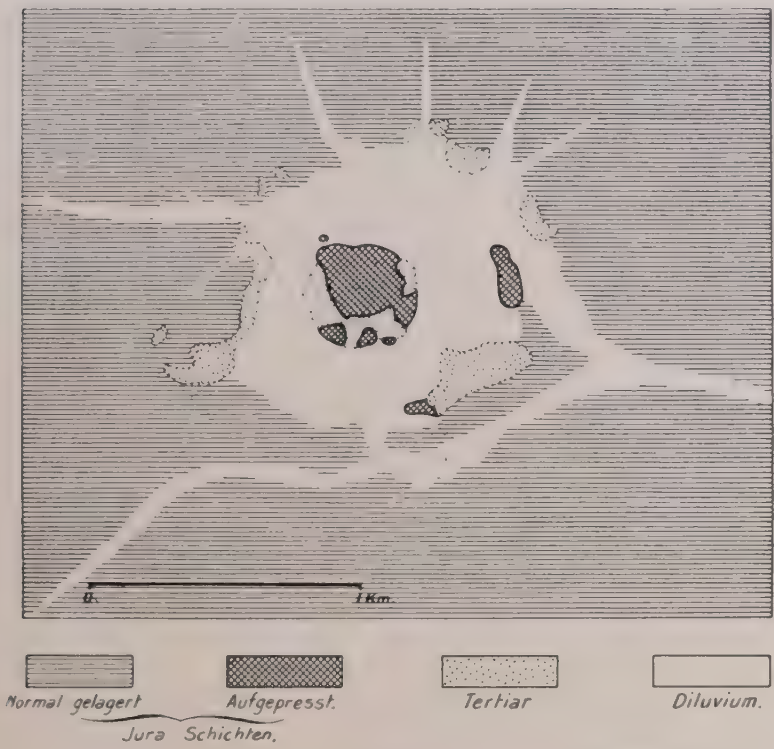

Fig. 8. Communication No. 39.

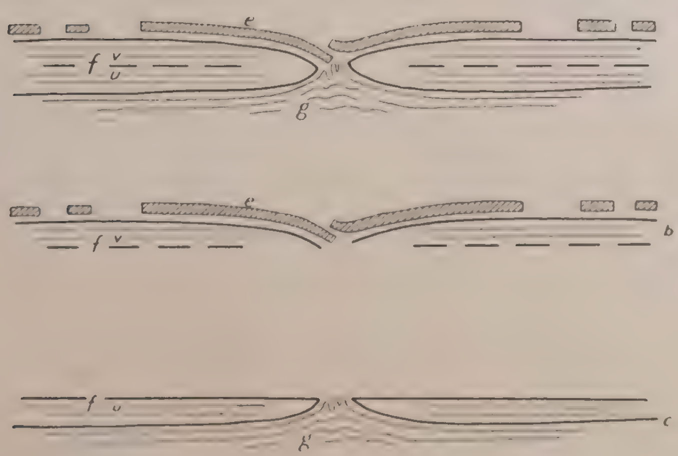

Fig. 9 Communication No. 39

40. GRABENTÄLER UND BRUCHZONEN IN MITTELEUROPA UND VORDERASIEN

VON

W. VON SEIDLITZ.

Das Senkungsgebiet des oberen Rheintales zwischen Schwarzwald und Vogesen und seiner nördlichen Fortsetzungen, das als eins der deutlichsten

Beispiele eines Grabenbruches gelten kann, wurde seit Jahrzehnten von Geologen der angrenzenden Länder untersucht und seine Randgebiete z.T. eingehend kartiert. Man sollte deshalb glauben, hier einem hinlänglich geklärtem Problem gegenüber zu stehen. Tatsächlich pflegt man es ja auch als ein Schulbeispiel dieser tektonischen Form anzusehen, das in fast alle Lehrbücher übergegangen ist. Aber die Erforschung der Bodenschätze dieses Gebietes hat uns in den letzten 20 Jahren, durch zahlreiche Bohrungen für Kali und Petroleum, in steigendem Masse Einblick in den Untergrund gewährt, sodass auch die früher anscheinend gesicherten Auffassungen über die Grundform schon mehrfach einer Revision unterzogen werden mussten. Die neuesten Untersuchungen zwingen abermals zu Ergänzungen. Welches andere Grabengebiet ist ständig so dem Wechsel der Erfahrung und Erklärung ausgesetzt gewesen? Es handelt sich hier aber nicht nur um Fragen von lokaler Bedeutung, zumal man die im Rheintal gewonnenen Anschauungen vielfach auf die ferner liegenden, meist nicht so gut erforschten und aufgenommenen Grabengebiete zu übertragen versuchte.

Es soll deshalb im Folgenden versucht werden, einige allgemeine Ergebnisse über Gräben, Grabentäler und Senkungsgebiete in verschiedenen Gegenden miteinander zu vergleichen. Ein wirkliches Ergebnis wird man aber erst dann erwarten können, wenn auch andere Grabenzonen mit dem gleichen Grade von Genauigkeit kartiert und evtl. auch durch Bohrungen untersucht sein werden wie das obere Rheintal.

Von den europäischen Gräben sind, neben vielen kleineren, kürzeren und weniger tiefen Senkungslinien am besten die erwähnte Grabenzone zwischen Schwarzwald und Vogesen, mit ihrer nördlichen Fortsetzung (Leinetal usw.) in Mitteldeutschland, bekannt, die Stille neuerdings mit dem Kristianiagraben im Norden und dem Rhonetal "graben" im Süden zu der Mittelmeer-Mjösenzone vereinigte. Es handelt sich dabei um ein System von Bruchgebieten, welches auf den ersten Blick weder im Alter noch im Bau oder dem Verlauf der Senkungen stärkeren Zusammenhang zeigt. Dennoch scheint es eine Bruchzone zu sein, die in ihrer Lage zu den Faltungsgebieten Europas eine gewisse Einheitlichkeit und daher Zusammengehörigkeit zeigt. Ein gleiches gilt von den Senkungsgebieten in Syrien und Palästina, die man ja mit dem erythräischen Bruchsystem des Roten Meeres zu einer grossen Einheit zusammenfasst. Zu diesem breiten Zerrungsgebiet, das man auch als nördliche Fortsetzung der ostafrikanischen Gräben anzusehen pflegt, gehören noch parallel verlaufende Brüche in Arabien und Lybien, denen z.B. der Nil in seinem Mittel- und Unterlaufe folgt. Für die *Gestaltung des östlichen Mittelmeeres* haben alle diese Bruchzonen besondere Bedeutung. Von einer gleichartigen Bauformel kann man aber in diesem erythräischen Gebiet nicht sprechen, da ebenso wie bei den mitteleuropäischen Gräben, die manigfaltigsten Formen der Senkung vorkommen, die auf verschiedenartige Anlage und Entstehung, wechselnden Alters, schliessen lassen.

I. Horst- und Grabenzonen.

1) *Längsbrüche, Querbrüche, Zerrungsbrüche.* Unter den vertikalen Dislokationen kann man vor allem drei Hauptformen unterscheiden, mit mancherlei Übergängen untereinander, von denen wohl die meisten Sonderfälle sich ableiten lassen. Jedenfalls unterscheiden sich diese vertikalen Bewegungen von den horizontalen nicht nur dadurch, dass sie zu ganz verschiedenen Zeiten entstanden, sondern auch dadurch, dass die einen unter Belastung (orogenetisch), die andern unter Entlastung (epeirogenetisch) sich bildeten. Als Reaktion auf Vorland und Untergrund werden sich während der orogenetischen Phase vor allem horizontale (Blatt-) Verschiebungen herausbilden. Von Wichtigkeit ist dabei, dass diese horizontale (transversale) Komponente bei fast allen grösseren Querbrüchen eine Rolle spielt.

Längsbrüche stehen vielfach mit Senkungserscheinungen am Aussenrande (Vorland) oder einem inneren Abbruch (oft Rückland oder inneres Zwischengebirge) eines Orogens in Zusammenhang. So sind Ebrobruch und Guadalquivirbruch im isostatischem Ausgleich der Meseta gegen Pyrenäen und Sierra Nevada, Donauflexur zwischen Alpen und deutschen Mittelgebirgen und Erzgebirgsbruch gegenüber der Böhmischen Masse entstanden.

Die meisten *Querbrüche* sind während oder nach einer Faltenerhebung entstanden und sehr oft mit transversalen (Blatt-) Verschiebungen verbunden. So kann man den Judikarienbruch, ebenso wie die Rheintalflexur (Säntis, Ostalpengrenze) als grosse Blattverschiebungen und als Verzögerungsmomente in der Nordbewegung der Alpen ansehen. Andere tiefreichende Bruchlinien wie die Otzbergspalte (Odenwald), Ruhla-Brotterodebruch Thüringen), Markircher (Vogesen-) und Elztal (Schwarzwald) Linie wird man als Scherflächen und Ausgleichslinien (Mohrsche Linien) bei den grossen Bewegungen ansehen können.

Zerrungsbrüche werden theoretisch an vielen Stellen angenommen; sichere Beweise für diese Annahme fehlen aber meistens und sind bisher wohl nur experimentell erbracht worden. Am ehesten kann man die erythräischen (Rotes Meer, Jemen) und ostafrikanischen Brüche mit ihren starken vulkanischen Begleiterscheinungen dazu rechnen.

Da alle diese Arten von Brüchen häufig gestaffelt und in Bruchzonen vereinigt auftreten, können zwischen parallelen Brüchen auch einzelne Schollen geschleppt werden, zurückbleiben oder sinken und andere gehoben werden. So können Senkungen und Grabenbrüche aus jeder dieser Grundformen entstehen, sowohl auf Vorlandsbrüchen, Rücklandsbrüchen, Quer und Zerrungsbrüchen. Beispiele für Vorlandsbrüche sind der Rhonetalgraben, für Rücklandsbrüche die kleinen Grabenzonen im Thüringer Becken (Wachsenburg, Leuchtenburg), für Querbrüche der Tafeljura und für Zerrungsbrüche sicher das Rote Meer.

2) *Grabenbrüche. Positive Gräben und negative Horste.* Als eigentliche und echte *Grabenbrüche*, die sich auch morphologisch deutlich abheben

und mit ihrer ursprünglichen Sohle auch meist weit unter den heutigen Meeresspiegel hinunterreichen (Totes Meer, Tanganjika, Njassa), pflegt man solche Senkungsgebiete zwischen gleichartigen Randgebieten und gestaffelten Brüchen zu bezeichnen, von denen man annimmt, dass bei ihrer Entstehung vor allem Zerrungsvorgänge eine bedeutende Rolle gespielt haben. Grabenbrüche sind ferner in der Regel dadurch charakterisiert, dass ihrem Senkungsraum seitliche Gebirgszonen parallel verlaufen, die wohl oft nur einen sekundären randlichen Massenausgleich gegen die Senkung der Mitte darstellen. Diese Randzonen brauchen nicht immer die Gestalt von Horsten anzunehmen, ebenso wenig wie Horste nur selten mit randlichen Gräben verbunden sind. Daneben gibt es *einseitige Gräben*, die meist diesen Namen ohne Berechtigung führen. Es sind solche, deren Randgebiete, wie beim Rhonetalgraben, verschiedenen Orogenesen (z.B. Alpin und variszisch) entstammen und die nur eine Art von Vorlandssenke darstellen.

Der Massenausgleich ist auch nicht allein auf den Rand beschränkt, sondern kann ebenso wie er durch staffelförmiges Absinken der Randzonen (Rheintal) gekennzeichnet ist, zu schwächeren Aufwölbungen und Heraushebungen in der Grabenmitte führen, wie dies die durch Horstschollen getrennten Kalibecken des Oberrheintales und andere Zwischenhorste in kleineren Grabenbruchsystemen (Thüringen) zeigen. Die Bewegungen der gehobenen und gesunkenen Teile sind vielfach relativ differenziert und zeigen im Lauf der Entwicklungsgeschichte mancher Grabensysteme mehrfachen Wechsel (Rheintal). Man könnte deshalb auch von *positiven Gräben* sprechen, wo vermutlich nur ein Einbruch erfolgte (Jordantal), im Gegensatz zu negativen, bei denen auch eine Heraushebung der seitlichen Horste (Rheintal, Bekaa) erfolgte. Ebenso wären als *positive Horste* solche zu bezeichnen, die durch Absinken der Randschollen entstanden, als *negative* aber solche, wo eine Aufpressung aus dem Untergrund (Thüringer Wald) erfolgte.

3) *Diagonale Störungen, Randschollen und Vorbergzonen.* Wie alle Bruchbildungen von regionaler Bedeutung, haben die meisten Grabenbrüche eine längere und wechselvolle Bildungsgeschichte, die auf alte Entstehung hinweist, wenn auch die Schichtenfolge ihrer heutigen Umgebung nur über die jüngsten Stadien berichtet. An der Mittelmeer-Mjösenzone haben so Bewegungen von der Devon—bis zur Tertiärzeit teilgenommen. Auch bei den Bruchzonen des östlichen Mittelmeeres muss man annehmen, dass ältere als tertiäre Anlagen vorhanden sind.

Dies geht schon daraus hervor, dass im Streichen solcher regionaler Bruchzonen der lokale Verlauf zwar beträchtliche Veränderungen und Ablenkungen erleidet (Afrikanische Gräben), während die Gesamtrichtung dadurch nur wenig beeinträchtigt wird, ob Faltungs- und Hebungszonen die Grabengebiete schräg oder quer schneiden (Syrische Gräben). Eine Querverschiebung in der Richtung der Senkungsachse (zwischen Rhein- und Rhonetalsenke) kann dadurch aber ebenso entstehen, wie eine Veränderung in der

Höhenlage der Grabensohle (Syrien). Im Zusammenhang damit müssen auch die *diagonalen Störungen* und Scherflächen, die aus den randlichen Hochgebieten gegen die Grabenmitte zu z.T. convergieren, erwähnt werden, die an manchen Stellen (mittleres Jordantal), besonders in schmalen Senkungsgebieten, ebenso am Zustandekommen der Grabensenke beteiligt sind, wie die randlichen Staffelbrüche oder Flexuren. Es scheint, dass solche nach innen convergierende Diagonalsprünge (Mohrsche Linien) für Senkungsgebiete und die Ablenkung von Bruchzonen (Ostafrikanische Gräben) ebenso von Bedeutung sind, wie bei Hebungsgebieten (Horsten), die nach aussen divergierenden Spalten, die am Thüringer Wald z.B. bajonettförmig absetzend, spiesseckig nach aussen springen. Dort wo ältere Hebungs- oder Senkungszonen (Schwellen oder Becken) eine Grabensenke queren, werden auch die randlichen Staffelbrüche dadurch beeinflusst und eine besondere Gestaltung erfahren (Bruchfeld von Rufach und Zabern im Rheintal). Es ist aber gar nicht nötig, dass überhaupt *Randschollen* und *Vorbergzonen* (Rheintal, Bekaa) vorhanden sind. An manchen Stellen werden sie durch sekundäres Absinken randlicher und oberflächlicher Randpartien (Niltal) nur vorgetäuscht; an anderen werden die Randstaffeln wieder stärker durch randliche Diagonalsprünge beeinflusst (Jordantal), sodass das normale Grabenschema, wie im Rheintal, durchaus nicht an allen Stellen anzutreffen ist. Den abgesunkenen Vorbergsschollen der Gräben entsprechen in Horstgebieten die Vorstaffeln (Thüringer Becken, Seeberg bei Gotha).

Auf eine andere auffallende Erscheinung vieler Grabengebiete sei hier aufmerksam gemacht. Das ist die annähernd gleichmässige Breite mancher der erwähnten Grabensenken. So hat das Rheintal eine durchschnittliche Breite von 30 km. in Ostafrika der grosse Graben 40-45 km; Taganjika 50 km; Njassa 25-30 km; in Syrien die Bekaa 8-14 km. und der Jordangraben 9-15 km., während das Rote Meer durch seine Breite von ca 300 km. sich wesentlich unterscheidet. Bemerkenswert ist auch, dass der Rheintalgraben von Basel bis Mainz 280 km., der eigentliche Jordangraben ca 240 km., die Muldensenke der Bekaa in Mittelsyrien aber nur 120 km. lang ist.

4) *Bruchzonen und Faltungsgebiete.* Die eigentlichen Grabenbrüche scheinen den *Faltungsorogenen* fremd zu sein, wenn auch manche Grabengebiete mit weiterreichenden Erhebungszonen oder Achsen zusammenfallen und gewissermassen, um ein altes Beispiel zu wiederholen, in seltenen Fällen einen Einbruch im First der Erhebungs- oder Aufwölbungszone darstellen. Jedenfalls scheint keine der Grabensenken in die Orogene einzudringen, sondern vor dieser Halt zu machen. Innerhalb der Orogene haben wir wohl Becken- aber keine echten Grabenbildungen (diese nur im Vor- und Rückland) und die Senken der Vortiefen kann man ebenfalls nicht als solche ansehen, da ihre Senkung meist einseitig und die Grabenränder verschiedenartig gestaltet sind (Rhonetal.) Zwar hat C. Schmidt schon vor langer Zeit darauf aufmerksam gemacht, dass die Rheintalsenke sich ins

Innere der Alpen in der Form einer Depression, wie wir heute sagen würden. fortsetzt und Weber glaubt die gleiche Richtung der N-S-Brüche sogar noch in der Küstengestaltung Sardiniens und Korsikas weider zu erkennen. Es kann sich dabei aber nur um Brüche die älter als die Faltung sind, d.h. um Brüche etwa aus der Zeit der variszischen Orogenese handeln, die ja auch im Rheintal, vielleicht sogar in der Form horizontaler Verschiebung zwischen Schwarzwald und Vogesen angenommen werden.

Tatsächlich finden die echten Grabensenken, die meist den Vorländern der Faltung angehören, am Aussenrande des Faltungsgebietes ihr Ende oder mit andern Worten, sie scheinen teilweise mit dem Faltungsdruck, der vom Gebirge ausgeht, und mit der Senkung des Vorlandes in Zusammenhang zu stehen. Es ist jedenfalls auffallend, dass der Rheintalgraben nördlich von einer markanten nach Norden gerichteten Biegung der Alpen bezw. der alpinen Vorfalten des Jura seinen Ausgang nimmt. Ebenso der Kristianiagraben südlich und senkrecht auf einen nach Süden gerichteten Faltungsbogen des Caledonischen Gebirges und die nördlichen Syrischen Gräben im südlichen Vorland des nach Süden gerichteten Taurusbogens, wie der Jordangraben südlich der Hermon-Libanonfalten. Nur in seltenen Fällen, nämlich dort, wo eine ältere Depression vorhanden ist, scheinen Bruchzonen des Vorlandes auch in den Faltungsköper mehr oder weniger tief einzudringen (Schweizer Jura, Aegäidenfaltung der Griechischen Inseln), dagegen nicht im Bereich einer Kulmination wie am Taurus. Es ist aber selbst hier die Frage, ob nicht diese Depressionen mit einem älteren Vorstadium der Bruchbildung zusammenhängen. In der Nähe der Faltenketten vereinigen sie sich oft mit kürzeren und lokalen Senken, die man als grabenförmige Vortiefen ansehen kann (Sundgau; "Graben" von Marasch am Taurus).

5) *Vorlandsbrüche und Rücklandsbrüche.* Gräben des Rücklandes sind ebenso, wie die der Vortiefen, meist nur von kürzeren Verlauf und geringerem Tiefgang, d.h. flacher gebaut, wie z.B. die kleinen, aber besonders instruktiven Grabenzonen im nördlichen Rückland des Thüringer Waldes (Thüringer Becken) zeigen.

Dort wo gestaffelte Grabensenken im Gebiet einer Depression auch in die Faltungszone eintreten, zeigt es sich, dass sie sich in viele einzelne Parallelsprünge aufsplittern können, sodass der einstige Senkungscharakter ganz oder zeitweilig verloren geht. Je nach dem Widerstand des Rücklandes der Faltung oder des Untergrundes zeigt sich an ihnen dann auch häufig die Tendenz zu transversalen Blattverschiebungen einzelner Schollen in der Richtung des Faltungsdrukkes. Ebenso werden Rücklandsgräben und grabenförmige Vortiefen oft von transversalen Querbrüchen, senkrecht zum Faltungsgebiet, zerstückelt (Thüringen) und verschoben.

Umgekehrt zeigt es sich, dass ältere Transversalverschiebungen (die man ja auch in der Grundanlage des Rheintalgrabens annimmt), bei Neubelebung in grabenförmige Senken übergehen, wie die variszische Ruhla-Brotteröder

Querverschiebung in Thüringen in die junge randliche Grabenzone Thal-Eisenach. Überhaupt scheint der Wechsel der Gestaltung grabenförmiger Senken, sowohl in historischer Folge, wie in räumlicher Erstreckung, ein sehr manigfaltiger zu sein. Nicht nur, dass verschieden alte Grabensenken sich zu regionalen Bruchzonen vereinigen und aneinander *anbauen*, bei denen die Tiefe des Einbruches, aber auch oft die Richtung, wechselt oder an Querstörungen beträchtliche Verschiebungen erleidet, sondern man kann an kleineren Grabenzonen (Thüringen) auch beobachten, dass Horst- und Grabenschollen im Streichen der Senken (Wachsenburg-Seeberg) miteinander abwechseln.

6) *Grabentäler.* Als echte Gräbensenken oder *Grabentäler* möchte ich daher nur diejenigen bezeichnen, die im Vorland mehr oder weniger senkrecht von einer Faltungszone ihren Ausgang nehmen und anscheinend durch deren Faltungsdruck, gleichgültig, ob schon ältere Anlage vorliegt oder nicht, beeinflusst werden. Alle anderen Gräben zeigen im Gegensatz zu ihrer regionalen Gestalt nur kürzeren Verlauf von lokaler Bedeutung; ebenso ist dort die oft sekundäre Bruchbildung mehr oberflächlicher Natur und greift selten in so grosse Tiefen hinab, wie bei den echten Grabentälern.

Damit hängt es wohl auch zusammen, dass eigentlich nur in der Umgebung dieser tiefgreifenden Bruchgebiete Erdbeben und vulkanische Erscheinungen sich bemerkbar machen. Seltener sind diese an die eigentlichen Randspalten gebunden, dagegen häufig an die Quer- und Diagonalsprünge (Syrien).

II. Rheinische und Thüringische Senken.

1) *Thüringer Becken.* Wenn auch die saxonischen Gräben *Thüringens* Hessens und Niedersachsens im Vergleich mit den echten Grabentälern nur sehr flach sind, so kann man an ihrer wechselvollen Gestaltung doch manche Feststellungen machen. Die hercynisch gerichteten Gräben des Thüringer Beckens liegen im Rückland der jungen Herauspressung des Thüringer Waldes, die durch einen von Norden wirkenden Druck verursacht wurde. Gleichzeitig mit dieser jüngsten Phase in der Bildung des Thüringer Waldes entstanden die—spiesseckig ins nördliche und südliche Vorland vorspringenden—diagonalen Scherflächen an den Aussenrändern und die Senken im Vor- und Rückland. Ein gleiches können wir nach WILSER am Schwarzwald Horst boobachten. Den Vorbergen des Rheintales entsprechen hier der kleine Thüringer Wald und die Bruchzonen im Süden, den hercynischen Gräben im Innern aber die Gräben des Thüringer Beckens.

Ebenso wie die älteren, gleichgerichteten Brüche des Thüringer Waldes (Frankenwälder Quersattel, Berbergsattel) vor allem in den variszischen Mulden in Erscheinung treten, sind auch die jungen Störungszonen des

Beckens abhängig von den alten Hochgebieten und Senken. Daher treffen wir auch keine durchlaufenden Senkungsgebiete grabenförmiger Gestaltung, sondern Störungszonen, aus einzelnen Grabensenken zusammengesetzt. Gegeneinander sind sie quer verschoben und besonders in den tief mit Sedimenten erfüllten Einmuldungen, die der alten variszischen Faltenrichtung folgen, gut ausgebildet. Grabenförmige Senken werden vielfach von sehr schmalen und zersplitterten Aufpressungshorsten begleitet. An Querverwerfungen wird oft ein Graben von einem Horst abgelöst (Wachsenburggraben-Seeberghorst.)—Meist sind aber nicht nur einfache Gräben vorhanden, sondern innerhalb der Senken werden sie von longitudinalen Horstschollen geteilt. Wichtig ist auch, dass die umgebenden Triastafeln meist ganz ungestört blieben und dass der Senkung der Gräben keine entsprechend breiten Horste am Rande entsprechen, wie im Rheintal. Auch die randlichen Staffelbrüche, die die rheinischen Vorbergszonen bei der Heraushebung der Randhorste schufen, scheinen gänzlich zu fehlen, sodass man sagen kann, dass die saxonischen Bruchzonen, wenigstens Thüringens, wenn sie auch äusserlich grabenartige Senken bilden, doch einen andern Typus als die echten Grabentäler darstellen.

2) *Oberrheintal.* Die Grabensenke des *Oberrheins* ist besonders dadurch charakterisiert, dass staffelförmige Randbrüche vorhanden sind, die in den Gebieten, wo das Grabental alte Depressionen oder Kulminationen durchschneidet, besonders stark gegliedert und abgesetzt sind (Rufach; Zaberner Bucht). Ihre jugendliche Anlage, zusammen mit der Heraushebung der Randhorste, geht daraus hervor. Wie die Kalibohrungen gezeigt haben, wechseln in der Grabenmitte auch Hoch- und Tiefschollen, meridionaler Richtung, miteinander, derart, dass die Kalisalze jetzt nur noch in drei, durch Quer- und Längshorste getrennten, Becken vorkommen. Vor allem ist ein Sattel bemerkenswert, der von Pfirt in der Grabenmitte nach Norden zieht und das elsässische und oberbadische Kaligebiet (Buggingen) voneinader trennt. Der Charakter der schon variszisch angelegten Senke wird wohl vor allem auch durch das Aufsteigen der randlichen Horstgebiete verstärkt, die ursprünglich noch nicht in der heutigen Höhe bestanden. Dadurch erst wird, freilich nur in diesem Teil, die Mittelmeer-Mjösensenke zum Grabental; eine Parallele zu diesem Vorgang finden wir im Grabental des Jordans in der Syrischen Senke. Diagonale Querverwerfungen verschiedenen Alters, vor allem aber als Folge dieser letzten Heraushebung, ragen von den seitlichen Horstgebirgen als fieder-förmige Scherflächen in die Senke hinein. Meist in gleicher Richtung treten im Innern und am Aussenrand der Horste auch lokale Grabensenken (Bonndorf, Freudenstadt, Hohenzollern) von geringer Tiefe und Bedeutung auf, die, wie die Erdbeben (z.B. 16:11.11.) zeigen, noch nicht ganz zur Ruhe gekommen sind. Keiner dieser jungen sekundären Gräben erreicht das Hauptgrabental; ebenso läuft keiner ihm direkt parallel, mit Ausnahme der kleinen Senke von Eberbach am Neckar. In seinen süd-

lichen Abschnitt teilt sich dann das Grabental, mit Annäherung an das viel jüngere Faltengebirge, in zwei Äste, von denen der nach Westen gerichtete Sundgau schon Vortiefencharakter hat.

III. Syrische Gräben.

1) *Abhängigkeit von den erythräischen Brüchen.* Ebenso wie bei mitteleuropäischen Gräben, kann man auch bei den *Syrischen* und nordafrikanischen Bruch- und Grabensystemen einstweilen nur die wichtigsten Erscheinungen registrieren, ohne dabei ein einheitliches Schema des Grabenbaues und der grossen Grabentäler zu finden. Schon O. Frass verglich das Gebiet des Bekaa Coelesyriens mit der Einsenkung des Rheintales und Libanon und Antilibanon mit Schwarzwald und Vogesen. Noch deutlicher erscheint die grabenförmige Einsenkung beim Jordantal mit dem Toten Meer, dessen Sohle bis 703 m. unter den Meeresspiegel reicht. Beide Gebiete, die von den Falten des Hermon und des südlichen Antilibanon getrennt werden, stellen Teile des grossen Syrischen Bruchsystems dar, das man gewöhnlich als eine Abzweigung des Roten Meer-Grabens ansieht und das vom Golf von Akaba bis 793 m. unter den Meeresspiegel reicht. Beide Gebiete, die von den Falwie 6 Breitengrade erstreckende Bruchsystem zeigt sehr verschiedene Formen der Grabenbildung, denen aber ungefähr gleiches Alter und die nur wenig wechselnde Streichrichtung von S nach N oder SSW nach NNO gemeinsam ist. Der mittlere Teil in Palästina und Mittelsyrien gehört, nächst dem Rheintalgraben—dank Blanckenhorn's verdienstvollen Forschungen und Zusammenstellungen, zu den bestbekannten Grabengebieten der Erde. Eine zusammenfassende Untersuchung des ganzen Bruchgebietes und der Senkungszonen, unter einheitlichem Gesichtspunkt, steht aber noch aus. Der Golf von Akaba und das anschliessende Wadi el Araba, den südlichsten Teil der ganzen Zone, hat man als eine nordöstliche Abzweigung des Roten Meeres angesehen. Dies gilt sicher nicht für die gesamte Bruchzone bis zum Taurus.

2) *Verschiedene Gestaltung und einzelne Teile des Bruchsystems.* Der nördliche Teil der Grabenzone, der aber keine echten Grabentäler mehr aufweist, steht augenscheinlich in ähnlicher Abhängigkeit vom Taurusgebirge, auf dessen Vorketten und Vorlandssenken er zuläuft, wie der Rheingraben zu den Alpen. Es fragt sich nur, ob man ein gleiches nicht von den ganzen N-S gerichteten syrischen Brüchen annehmen kann, die sich dann südlich der Sinaihalbinsel mit der Bruchzone des Roten Meeres gekreuzt hätten. Näher liegend ist es aber, eine südliche und eine nördliche Bruchzone zu unterscheiden, die etwa im Gebiet des Hermon zusammentreffen und die zueinander dann etwa in gleicher Beziehung ständen, wie die einzelnen Teile der Mittelmeer-Mjösenzone in Europa. Wir hätten dann das nördliche System verschieden gestalteter und gerichteter Muldengräben (Bekaa) und gefalteter Vortiefen, in Abhängigkeit vom Taurus und das südliche

Grabental des Jordan in Abhängigkeit von Hermon und Libanon (Antilibanon). Ich neige dieser Auffassung umsomehr zu, als die Syrischen Brüche, denen noch die Küstenbrüche des östlichen Mittelmeeres zuzurechnen sind, augenscheinlich in engster Beziehung zu den eben erwähnten Syrischen Faltengebirgen und dem sogenannten *Syrischen Bogen*—als saxonischen Vorfalten der Eurasiatischen Kettengebirge—stehen, während das Rote Meer mit seinem System von parallelen und Querbrüchen einen ganz anderen Typus, vornehmlich des Zerrungsgrabens, darstellt.

Vielleicht wird man auch gut tun, den nördlichen Teil der Senkungszone, das Ghab—das Blanckenhorn noch zur Grabenzone rechnet—abzutrennen, wie es schon Kober vorschlug, da es sich um eine typische Senkung der Vortiefe der Taurusfaltung handelt. Der "Graben" von Marasch kann deshalb höchstens mit der gleichartig gestalteten Rhonetalsenke verglichen werden, die auch keinen echten Grabenbruch darstellt, da sie von verschiedenartigen Randzonen begleitet wird. Die eigentliche Senke der Syrischen Gräben lässt sich demnach höchstens bis nach Antiochia verfolgen, wo sie sich mit dem Quergraben der Orontesmündung kreuzt. Dort trifft sie dann auch mit der Vortiefensenke des Mons Cassius zusammen. Somit bleiben in der Hauptsache nur die Jordansenke bis südlich des Toten Meeres und in Mittelsyrien die von Leontes und Orontes durchflossene Senke der Bekaa übrig. Die erstere ist ein Grabental, wie das Rheintal, die andere ein Muldengraben mit gehobenen Randgebieten, denen aber diagonale Schersprünge fehlen. Ihr verschiedenes seismiches Verhalten bestätigt dies aufs beste. Beide werden mehrfach durch gehobene Schwellen gegliedert und begrenzt; ebenso können wir mehrere seitliche Abzweigungen nach Osten und vor allem nach Westen unterscheiden, die sicher mit schon älteren orogenetischen Anlagen und dem Einbruch des Mittelmeeres in Zusammenhang stehen. Auch einige Parallel- und Diagonalsenken sind innerhalb des Antilibanon vorhanden; die Syrischen Randbrüche des Mittelmeeres können wir wohl gleichfalls diesem System von Brüchen zurechnen.

3) *Alter und Anlage der Einbrüche.* Im allgemeinen ist das Alter der Einbrüche, ebenso wie beim Roten Meer, ein sehr junges und kann zwischen Miozän und Jung-Pliozän angenommen werden. Einige Veränderungen haben wohl auch noch im Diluvium stattgefunden, da der Abfluss des einst höher gestauten Tiberiassees und die diluvialen Terrassen des unteren Jordantales wohl eher durch ganz junge Absenkungen im Gebiet des Toten Meeres, als nur durch Verdunstung zu erklären sind.

Ebenso wie die jungtertiären Einbrüche nicht nur in einer Phase erfolgten, ist anzunehmen, dass auch schon viel ältere, heute nicht mehr erkennbare Anlagen der Grabenbildung vorliegen. Es könnte sich auch hier um Transversalverschiebungen handeln, etwa der östlichen Grabenflanke gegen Norden, worauf die Stauung und Virgation der Antilibanonfalten gegen die Palmyrene hindeutet. Die östlichen Grabenränder des Jordantales sind auch

stärker herausgehoben, so wie der Schwarzwald gegenüber den Vogesen, man erkennt dies daran, dass an ihnen allein ältere Schichten zu Tage treten; und zwar nicht nur im südlichen Teil am Ostufer des Toten Meeres und des Wadi el Araba, sondern auch im mittleren Teil wo neuerdings unter der Kreide auch Trias und Jura (Jabboktal) festgestellt wurden. Auch die Ausfüllung der Grabenmitte, sowohl im Jordantal wie in der Bekaa, mit diluvialen und jungtertiären Ablagerungen, die nur für die allerjüngste Geschichte von Bedeutung sind, geben uns keinen Aufschluss über die ältere Entwicklung. Es ist nicht einmal nachzuweisen, wieweit unter der fast überall verbreiteten Diluvialdecke tertiäre Ablagerungen in grösserer Ausdehnung vorhanden und wie tief die Talsenken mit jüngerem Ausfüllungsschutt aufgefüllt sind. Dadurch wird auch ein Vergleich des ca. 800-1100 m über dem Meeresspiegel liegenden mittelsyrischen Grabens (Bekaa) und des 200-800 m. unter dem Meeresspiegel liegenden Jordangrabens sehr erschwert. Da natürlich jeder künstliche Aufschluss in Gestalt von Bohrungen—die ja auch im Rheintal erst die Tektonik klar stellten—fehlt, ist auch nicht festzustellen, ob der Graben von Coelesyrien etwa auch unter den Meeresspiegel hinabreichte, die dies bei echten Grabentälern der Fall ist und ebenso tief eingesunken ist, wie das Jordangebiet. Man müsste in diesem Fall annehmen, dass er aus dem höheren, gebirgigen Einzugsgebiet von Libanon und Antilibanon oder andererseits durch direkte Verbindung mit dem tertiären Mittelmeer höher zugefüllt worden wäre als der grösstenteils von ariden Gebieten umgebene Jordangraben, mit seinen spärlichen Zuflüssen. Einstweilen kann man aber nur feststellen, dass zu den sonstigen Unterschieden zwischen beiden Grabensenken auch die Verschiedenheit in der Höhenlage der beiden Grabensohlen gehört.

4) *Die Grabentreppe Syriens.* Diese verschiedene Höhenlage der einzelnen Teile der Syrischen Grabenzone, die man auch als eine *Grabentreppe* bezeichnen kann, ist eine der auffallendsten Erscheinungen in diesem Senkungsgebiet, für die mir aus anderen Gegenden ein Parallelbeispiel nicht bekannt ist. Zwar wissen wir auch vom Rheintalgraben, dass sein Untergrund nicht nur sekundäre Längshorste in der Mitte, sondern auch einige Schwellen und Stufen, vor allem beim Zusammentreffen mit der alten Saar-Saalesenke, aufweist, aber stärkere Gegensätze sind dort nicht zu erkennen. Die Höhenverhältnisse zwischen den Gräben und den umgebenden Gebirgen sind im ganzen Verlauf der Grabenzone annähernd die gleichen. Die Stufenform tritt nicht nur zwischen Bekaa und Jordantal, sondern vor allem innerhalb des Letzteren (Hulesee +2 m., Tiberiassee—208 m., Totes Meer—392 m.) deutlich hervor und wird noch deutlicher, wenn man nicht den Seespiegel, sondern den Felsuntergrund berücksichtigt (Tiberias—278 m., Totes Meer—793 m.) Da der Libanon 3000 m. und der Antilibanon 2680 m. an Höhe erreicht, die Randgebiete des Jordantales aber nur zwischen 700 und 1000 m. liegen, fällt die Höhenlage der Gräben z.T. zusammen mit der grösseren

Höhe der Randgebirge. Es liegt daher nahe an eine Gesamthebung der einzelnen Blöcke an wichtigen Querstörungen zu denken, wie sie z.B. der Damaskusbruch zwischen Bekaa und Jordantal darstellt.

5) *Das Faltengebirge des Syrischen Bogens u. des Libanon.* Dies weist gleichzeitig darauf hin, dass die Faltenbildungen in der nächsten Nähe dieses Bruches Ursache und Hindernis zugleich für die Bruch- und Grabenbildungen gewesen sein müssen. Die Faltung von Libanon, Antilibanon und Hermon ist älter als die heute erkennbare Bruchbildung, sowohl der fächerförmigen Längsbrüche des Antilibanon, wie der Gräben. Was den Bau dieser markanten Randgebirge des Bekaa anlangt, so spricht DIENER nur von Schollenbildungen, KOBER andererseits weist dem Faltenbau solche Bedeutung zu, dass er den so ausgesprochenen Bekaagraben nur für eine Muldensenkung ansieht. Beide sind sich freilich darin einig, dass die Libanonfaltung keine alpinotype, sondern mehr eine germanotype Vorlandsfaltung des Taurischen Systems ist, was ja KRENKEL mit dem Begriff des Syrischen Bogens am deutlichsten ausdrückt. Aber nicht nur Libanon und Antilibanon gehören diesem von Ägypten nach Arabien hinüberziehenden Bogen an, sondern die ganzen Höhenzüge Syriens und Palästinas, in die Bekaa und Jordantal eingesenkt sind. Nur tritt die Faltung in dem einen Gebiet stärker hervor als in dem andern; am stärksten im Antilibanon. Aber auch in den anderen Gebieten sind die Faltenbiegungen zu erkennen, wenn sie auch durch die Blockzerstückelung vielfach verwischt sind. Ebenso wie ich glaube, dass die Bruch- und Grabentektonik sich auf mehrere, vielleicht sogar vortertiäre Phasen verteilt, scheint auch die Faltung der syrischen Gebirge mehreren Phasen der saxonischen Faltung zu entsprechen.

Während die Gebirge Palästinas, die ja nichts anderes als die südliche Fortsetzung des Libanon darstellen und die weniger erforschten Gebiete Transjordaniens N-S oder NNO-SSW gerichtete Falten- und Gebirgszüge erkennen lassen, springen die Gebirge des Antilibanons nördlich des Hulesses mit scharfem Knick gegen Osten vor und verlaufen nicht nur durch Parallelbrüche, sodern auch, in mehrere deutlich gegliederte Faltenzüge geteilt, nördlich der Damascene gegen Palmyra zu in die Arabische Wüste und gegen den Euphrat zu aus. Der Wiederstand für diese auffallende Faltung, die nördlich von Damaskus sogar in überkippten Falten endigt (die Hochfläche des Djolan fällt unter die Kreidefalten ein), ist in der Grundstruktur des starren Vorlandes der Arabischen Tafel zu suchen; ebenso wie sich im Norden die Tauruskketten an einem nördlichen Teilstück der gleichen Tafel stauen, das hier als äusseres Zwischengebirge wirkt. Die starken Basaltergüsse des Djolan, Hauran und nördlich der Gegend von Homs und Aleppo dürften mit Senkungs- bezw. Zerrungsvorgängen bei der Zerteilung dieser alten Tafel zu erklären sein. Ihre innere Struktur bleibt aber unter Wüstensand und jugendlichen Ablagerungen verborgen und erscheint nur in einigen Wadis des inneren Arabiens angedeutet.

Dreh- und Angelpunkt dieser Gebirgsumbiegung dürfte der *Hermon* (2773 m) sein, der zugleich eine der höchsten Erhebungen des ganzen Gebirgssystems darstellt und an dem der Jura bis zum Gipfel hinaufgefaltet ist. Dies legt die Vermutung nahe, dass hier in der Tiefe viel ältere Gesteine verborgen liegen, die—wenn sie nicht überhaupt Reste einer älteren Orogenese darstellen und dann selbst Ursache der Faltenabbiegung sind—doch mit dieser Erscheinung in engem Zusammenhang stehen.

An dieser *Hermon- und Antilibanonfaltung* sind südlich der Bekaa Grabenschollen eingeklemmt, die die Wasserscheide zwischen Jordan und Leontes bilden und ebenso die beiden so verschiedenartig gestalteten Gräben des Jordan und der Bekaa voneinander trennen. Der trennende Rücken des Djebel ed Dahr der über 1100 m Höhe erreicht, streicht schon den Antilibanonfalten und der SSW-NNO gerichteten Bekaa parallel, während im Jordangraben die N-S Richtung vorherrscht.

6) *Bekaa.* Betrachten wir beide Grabengebiete im Einzelnen, so ist die *Bekaa* anscheinend am typischsten ausgebildet. Sie ist aber nur als ein Muldengraben anzusehen, während das Jordangebiet einem echten Grabental entspricht. Im Westen wird die Bekaa von dem über 3,000 m hohen Libanon, im Osten von dem Schollenhochplateau des Antilibanons begleitet, dessen Höhen bis 2,680 m. ansteigen und dessen östlich abzweigende Falten als Virgation gegen die Palmyrene ausklingen. Die Talebene selbst liegt im Durchschnitt 800 m hoch, die Wasserscheide zwischen Leontes und Orontes, nördlich von Baalbeck erreicht ca. 1,200 m. Demnach liegt dieser 8-14 km. breite Graben, dessen Breite ungefähr der des Ghor (Jordantal) entspricht, etwa 1,500—2,200 m. zwischen die umliegenden Bergketten eingesenkt, was gleichfalls mit der Senke des Jordantales zu vergleichen ist, wenn man die Höhe vom Ölberg zur Sohle des Toten Meeres (1,500 m.) berücksichtigt. Nach Norden zu senkt sich das 120 km. lange Tal des mittelsyrischen Grabens, um am See von Homs bei 500 m. seinen tiefsten Punkt zu erreichen.

Blanckenhorn erklärt die Bildung des Jordantales zwischen Jerusalem und Jericho zwar durch eine flexurartige Abbiegung, dennoch muss es fraglich bleiben, ob diese mehr mit den primären Faltungen der Kreidegewölbe oder nur mit der Absenkung des Jordantales zusammenhängt. Wenn aber Kober das verhältnismässig schmale, jedoch—wie oben angedeutet—tief eingesenkte Tal der Bekaa nur als eine eingebrochene Synklinale erklärt, so kann das höchstens für einge Teile des verbreiterten Tales in der Nähe von Homs in Frage kommen. Im südlichen Teil ist die Bekaa sicher eine ausgesprochene Grabensenke, welche aber aus einer Mulde hervorgegangen ist. Diese Senke wird beiderseits von schmalen und niedrigen Vorhügelketten begleitet, die sich morphologisch auf dem Wege zwischen Baalbeck und Maalaka (Zalé) und fast noch deutlicher auf der Ostseite bei Bar Elias abheben. Die Schichten dieser Vorhügel, bei denen es sich nicht um

lokale Abrutschungen handeln kann, da sie den Hauptketten auf weite Erstreckung folgen, fallen im Westen z.T. östlich ein, während sie auf der Ostseite ein senkrechtes oder westliches Einfallen zeigen. Ausserdem ragen noch zwischen Ras Baalbek und Baalbek eine Anzahl kegelförmiger Hügel von senonen Kalken in die Mitte der Talsenke, deren starke Faltung von der wenig gestörten Schichtenlage der Randgebiete sich deutlich abhebt. Es fragt sich aber, ob dies gleichfalls Vorhügel sind, da sie sich auch petrographisch deutlich von den umgebenden Quartärschichten abheben, oder ob vielleicht Komplikationen des Untergrundes etwa in der Art von Längshorsten vorliegen. Auf der Ostseite begleiten die Bekaa, innerhalb der Schollen des Antilibanon, einige schmale Parallelsenken (östlich von Ez-Zebedani), durch die gleichfalls bestätigt wird, dass es sich um ein grabenförmiges Bruchsystem handelt.

7) *Jordantal.* Ganz anders ist die Gestaltung des *Jordantales*, das deutlich in Stufen abgesetzt ist, von der die oberste mit dem Hulesee (2 m. über dem Meeresspiegel) beginnend, etwa 43 m. hoch liegt und nur den vergrösserten Seeboden, vor der Anzapfung nach Süden, darstellt. Es folgt der Tiberiassee (— 208 m.) und schliesslich das Jordantal, das durchschnittlich tiefer als—300 m. liegt und sich bis zum Spiegel des Roten Meeres bis auf—392 m. senkt. An der tiefsten Stelle beträgt die Senkung der Sohle des Sees sogar 793 m., was einem Höhenunterschied gegen den Ölberg bei Jerusalem von fast 1,600 m. entspricht. Dass diese Senkung sehr jungen Datums ist, geht auch daraus hervor, dass das Gebiet des Toten Meeres gegenüber der übrigen Jordansenke ein besonderes seismisches Verhalten zeigt. Die südliche Fortsetzung im Wadi el Araba steigt wieder, sich stark verschmälernd, bis über 300 m. an. Am Ausgang des Golfes von Akaba kreuzt sich die syrische Senke mit dem Graben des Roten Meeres. Die grösste Tiefe des Golfes beträgt 1,200 m.; von der eigentlichen Senke des Roten Meeres ist er aber nochmals durch einen Abbruch von vielen 100 m. Sprunghöhe getrennt. Auch im Roten Meer selbt kann man mehrere ähnliche staffelförmige Abbrüche senkrecht zum Streichen des Grabens feststellen (grösste Tiefe 2250 m.), sodass sich daraus ergibt, dass eine solche innere Staffelstruktur, dort wo ältere Quereinflüsse sich bemerkbar machen, durchaus zum Typus, vor allem eines Zerrungsgrabens, gehört. Zufällig können wir dies an den noch nicht völlig zugeschütteten oder von Wasser bedeckten Senken des Jordantales und des Roten Meeres feststellen; aber unsere Kenntnis der bereits zugeschütteten und ausgefüllten Gräben ist noch zu lückenhaft, um festzustellen, ob es sich dort ebenso verhält.

Was die Beziehung des Wadi el Araba zum *Golf von Akaba* und zum Roten Meer anlangt, so kann man wohl sagen, dass—wenn auch die östliche Randspalte bis auf das Grundgebirge aufgerissen ist, diese schmale, stellenweise nicht mehr wie 5 km. breite, Senke unmöglich den Ausgangspunkt eines grossen Bruchsystems darstellen kann, wie es uns weiter nördlich in Palästina

und in Syrien entgegentritt. Diese südlichsten Ausläufer machen mehr den Eindruck einer ausklingenden, als einer einsetzenden Dislokation. Ich kann deshalb auch nur von einer Kreuzung der syrischen Brüche mit der erythräischen Zone sprechen, nicht aber in den ersteren eine Fortsetzung der ostafrikanischen Gräben sehen, wie dies von alters her angenommen wurde. Es sind die syrischen Brüche, die ihre Parallele ja noch in den Küstenabbrüchen, also in dem Ostrande des Mittelmeeres finden, genau so wie das Rote Meer und der Golf von Aden, Randbrüche der starren Arabischen Tafel, von der sich jüngere Randgebiete loslösen. Wenn es sich also bei den syrischen Brüchen auch um eine Zerrung handeln solle, so kann diese nur im Zusammenhang mit dem Einbruch des Mittelmeeres von Westen her erfolgt sein.

Was nun die Randbrüche des Jordangrabens anlangt, so sind sie nicht so einheitlich und gleichmässig auf beiden Rändern gestaltet wie die der Bekaa. Handelt es sich doch bei dem Gesamtlauf des Jordans allein (ohne das Wadi el Araba) um eine Strecke, die mindestens doppelt so lang ist wie die Bekaa und die aus verschiedenen Teilen zusammengesetzt ist. Morphologisch prägt sich auch dieses Tal, nicht nur in den verbreiterten und vertieften Seegebieten, deutlich genug aus. Seine Randgebiete sind aber nicht einheitlich gebildet und vielfach von Basaltmassen überdeckt. Nur die tief eingeschnittenen Seengebiete werden von parallelen Spalten begrenzt, derart, dass das Gebirge, vielfach direkt vom Seespiegel an, hoch aufsteigt und die Ufer vom Land aus nicht zugänglich sind. Besonders im eigentlichen Jordantal zwischen *Tiberias* und dem *Toten Meer* sind die Randspalten, vor allem auf der Westseite, anders gestaltet, während die Ostseite, die Abbrüche des Adschlun, eines Gebietes, das noch weniger erforscht ist, ebenso wie die Ostseite des Toten Meeres, einen gradlinigen Verlauf, freilich auch ohne jede Vorbergzone zeigt. Auf der Westseite des Jordantales fehlt ein einheitlicher Abbruch. Teilweise herrschen flexurartige Abbiegungen gegen den Graben vor (Jericho), teils handelt es sich um Randstaffeln und Diagonalbrüche, die aus dem Gebirge Judäas und Samarias nach NNO hinüberstreichen. Im Süden sind es die Bruchlinien von Hebron und die im Gebiet von Jerusalem, (die seismisch sich besonders bemerkbar machen), im Norden die Brüche von Nabulus, die als Artuflinie (Besan) die untere Jesreelebene erreichen und vielleicht sogar bis auf das Ostufer des Tiberias hinüberstreichen. Südlich von Besan, wo der Grabenbruch sich bis auf wenige Kilometer verengt, treten gestaffelte Kreideschollen bis fast an das Ostufer heran, sodass in diesem Teil der Grabenbruch wohl erst sekundär durch die Nord-Südbrüche seine Gestaltung erhielt, während die ursprüngliche Form, ebenso wie das auch schon für das nördliche Wadi el Araba angenommen wurde, durch gekreuzte Diagonalsprünge entstand. Die Sprungkreuzung fällt zusammen mit einem stufenförmigen Abbruch von ca. 200 m. der von der unteren Jesreelebene (um Besan) zum Ablagerungsge-

biet des pluvialen Toten Meeres führt. Auch die NW abzweigenden Brüche der Jesreelebene, die bis zum Karmel bei Haifa reichen und die Randbrüche des Berges Tabor gehören zu diesem System von Diagonalspalten, das dem ganzen Grabensystem fremdartig eingeschaltet ist und wie die fast vollkommene Bebenfreiheit zeigt, z.T. wohl einen älteren Bau verrät. Die Verengung des Jordantales südlich Besan hängt deshalb auch weniger mit der Grabensenkung, sodern mit der alten Anlage der stauenden Faltung zusammen. Schliesslich bildeten sich hier im Zusammenhang mit der Senkung des Mittelmeeres auch die O-W und WNW-OSO Quersenke der Jesreelebene und die ihr parallelen Querstörungen, die anscheinend schon älter als die Grabenzone sind und mit ihr nur sekundär in Verbindung stehen.

Die Brüche und Falten Judäas und Samarias in SWW-NNO und O-W Richtung stellen, wie Krenkel erwähnt, einen südlichen Abschnitt des syrischen Bogens, den Antilibanonfalten parallel verlaufend, dar. Sie vertreten die älteste Richtung des Gebietes und greifen, da sie älter als der Grabenbruch sind, auch auf die Ostseite hinüber (Bruch von Es Salt and Störungsgebiet von Derat.) Auf der Westseite entsprechen ihnen in Galliläa die Brüche und Senken von Nazareth, der Ebene Asochis und vermutlich die Störungen bei Safed und östlich von El-Bassa. Jünger sind die NW gerichteten Brüche des mittleren Jordantales, und der Jesreelebene am jüngsten anscheinend die N-S Brüche des eigentlichen Grabens. Welche von diesen Linien etwa gleichzeitig entstanden, scheint noch nicht vollständig geklärt. Vielleicht handelt es sich hier auch um mehrere verschiedene Phasen der Bewegung.

Die Stufen und Abbrüche scheinen in der Hauptsache, ebenso wie zwischen Hulesee und Bekaa, durch die SSW-NNO Brüche veranlasst zu sein. Hierzu würden gehören der nördliche Abbruch des Libanon gegen den Nahr el Kevir (kleine Bekaa), die südliche Randspalte der Bekaa bei Dschubb Dschenin, der Abbruch der Ebene des Hulesees am Damaskusbruch, des See Tiberias gegen letzteren, der Jesreelebene gegen das weitere Becken des Toten Meeres und schliesslich der Südrand des Toten Meeres gegen das Wadi el Araba; im Norden vielleicht auch noch die schmale Senke der Orontesmündung und von Antiochia.

8) *Erdbeben und Vulkanismus.* Es sind dies gleichzeitig diejenigen Linien, die durch Erdbeben und vulkanische Ausbrüche bemerkenswert sind. Mit wenigen Ausnahmen sind die Basaltausbrüche auf diese Diagonalspalten oder deren Kreuzung mit den N-S Grabenrändern beschränkt. Die einzigen Gebiete, wo die Basaltmassen des Ostens auf die Westseite der Gräben übergreifen, befinden sich in der Umgebung der Bruchkreuzungen am Tiberiassee und am Nahr el Kebir bei Homs, dessen Einsenkung einer tiefgreifenden Anlage anzugehören scheint, da in ihrer Fortsetzung im Mittelmeer das Tief südlich Cyperns folgt. In diesem Zusammenhang sei auch

die enge seismische Beziehung zwischen Cypern und dem Gebiet von Aleppo erwähnt.

Die Erdbeben des Gebietes der syrischen Gräben gingen meist nicht von diesen selbst aus, sondern von den SSW-NNO Brüchen. Das Erdbeben vom 11. Juli 1927 hatte seinen Ursprung—wie SIEBERG überzeugend nachgewiesen—nicht im Jordangraben, sondern in dem System sich kreuzender Spalten in Samaria bei Nabulus, an der Kreuzung der idumäischen SW-NO Brüche mit dem NW-SO System der Jesreelebene. Das sekundäre Maximum bei Er Rene—Kafr Menda liegt in dem zerstückelten Schollengebiet westlich des Tiberiassees und ein anderes bei Ludd-Ramleh auf dem versenkten Abbruch des Hochlandes gegen die Küstenniederung. Auch frühere Beben, so bei Safed, waren meist an die Diagonalbrüche, nicht aber an den Graben gebunden. Die Ruinenstätten von Palmyra (Damaskusbruch) und Baalbeck zeugen von der Erdbebenwirkung in früheren Jahrhunderten.

Von der nördlichen Fortsetzung der syrischen Gräben erwähnte ich schon, dass man wohl weitere Senken am Rand der Vorgebirge des Taurus feststellen kann, dass dies aber keine echten Grabenbrüche, sondern Einmuldungen der Vortiefen sind, bei der die Ränder verschiedenartig gestaltet sind. Die Grabenbrüche greifen deshalb auch nicht in den Körper des Faltengebirges hinein.

Wichtig sind noch die Parallelsprünge zu den Gräben. Eigentliche Horste scheinen nur auf der Westseite vorhanden zu sein, wenn man nicht nach DIENER's Auffassung den Antilibanon als solchen ansehen will. Den Libanon wird man dazu rechnen müssen. ZUMOFFEN verzichtet leider auf seiner schönen, neuen Karte gänzlich auf eine Darstellung der Tektonik. Auch das Hochland von Palästina erhält durch die staffelförmigen Randbrüche gegen die Küstenebene Horstcharakter. Rechnet man noch den ganzen Abbruch der syrischen Küste hinzu, so reichen die Aussenstaffeln noch tiefer hinab, wie die Gräben selbst. Auch auf der Ostseite, wo die gesamte Arabische Tafel als Gegenhorst anzusehen ist, müssen parallele Brüche vorhanden sein, wenn wir sie einstweilen, auch nur stellenweise z.B. aus dem Gebiet von Petre im Süden und Maarat bei Aleppo im Norden kennen.

IV. ERYTHRÄISCHE BRUCHGEBIETE.

Die Tatsache, dass die syrischen Beben bis nach Oberägypten (Keneh, Luxor) gespürt wurden, legt die Vermutung nahe, dass der syrische Graben, wie schon erwähnt, keine Abzweigung des Roten Meeres ist, sondern dieses nur überschneidet und in Brüchen bis in die Gegend von Luxor fortsetzt, wie schon aus den Beobachtungen von E. FRAAS hervorgeht. Jedenfalls wird das Gebiet des Roten Meeres nicht nur von den Hauptbrüchen erythräischer Richtung, die zudem noch von einer Reihe von Parallel-

brüchen begleitet werden (RATJENS erwähnt aus Jemen ein ganzes System von parallelen Staffelgräben und Staffelhorsten), gestaltet, sondern noch von einer anderen quer dazu verlaufenden Gruppe, die KRENKEL als die Brüche der Somalirichtung bezeichnet hat. Auf sie sind die Tiefenstaffeln des Roten Meeres zurückzuführen und wie SIEBERG dargelegt hat, auch die hauptsächlichsten Gebiete der vulkanischen Ausbrüche und der Erdbebencentren, die an der Kreuzung erythräischer und der Somalibrüche auftreten.

1) *Niltalbrüche.* Zu den Parallelbrüchen des Roten Meeres gehören die Nilbrüche, denen der Fluss in der NW-Richtung bei Berber, Dongola und schliesslich von Keneh bis Assiut folgt. Einige dieser Brüche, besonders in der Umgebung von Keneh sind als Grabenbrüche ausgebildet. Am Nilknie von Keuch stossen zwei Bruchrichtungen deutlich aufeinander. Die abgesunkenen Schollen sind der Lybischen Hochfläche vorgelagert, so wie sie auch bei Theben (Luxor) im Tal der Königinnen und bei Medinet Habu deutlich als Bruchschollen mit Einfallen gegen den Berg auftreten. Würde es sich nur um lokale Unterwaschungen handeln, so würden Bergsturzmassen eine grössere Rolle spielen. Auch zwischen Luxor und Esne treten diese Abbrüche auf der Ostseite nahe an den Fluss heran und bezeugen die tektonische Anlage des Tales.

Grabenartige Senken, mit beiderseitigem Einbruch, treten aber nur selten hervor und bei der komplizierten Zusammensetzung des Nillaufes kann man wohl nur sehr kurze Strecken als solche ansehen. In erythräischer Richtung kommt das Gebiet nördlich Esne, in Somalirichtung (SW-NO), die Gegend westlich von Keneh und das Gebiet westlich und südlich von Luxor in Frage, wo man am Ghebel Gar, an den Talhängen des nach Norden zu (Luxor) verlaufenden Wadi, ganz deutlich diese Schollenabbrüche feststellt.

Auch die Oasen, als Depressionsgebiete, die z.T. von Brüchen begrenzt werden (Fajum, Baharije) scheinen den beiden Richtungen, die uralten Anlagen der afrikanischen Scholle entsprechen, zu folgen. Für das erythräische Gebiet ist es jedenfalls wichtig, dass hier die Wirkung des grossen und breiten Zerrungsgrabens nicht nur mit seitlichen Horsten abschliesst, sondern dass ihm, besonders auf der Westseite, noch eine ganze Reihe von Parallel- und Querbrüchen folgen. Auf der Ostseite ist ein gleiches nur zu vermuten, da der grösste Teil des Landes der Forschung noch verschlossen ist.

2) *Bruchzonen des östlichen Mittelmeeres.* Noch bedeutsamer ist der Einfluss der erythräischen Senke und ihrer Randbrüche auf das *Mittelmeergebiet.* Die Brüche des Roten Meeres lassen sich ebenso wie die Brüche des unteren Nillaufes, als westliche Randstaffel, weit in das Gebiet des Aegäischen und Jonischen Meeres verfolgen. Die Verbreitung des Levantebebens vom 26. Juni 1926 und des Palästinabebens vom

11. Juli 1927 hat gezeigt, dass sie an Schollen gebunden sind, die mit der Fortsetzung dieser Bruchlinien des Roten Meeres zusammenfallen. Das Palästinabeben wurde bis Luxor, Alexandrien und Rhodos verspürt. Das Levantebeben ebenfalls bis Luxor, Port Said, Alexandrien, Rhodos, im Nordwesten aber bis zu den Jonischen Inseln und nach Ancona. Die so bewegten Schollen werden, nach Siebergs Karte, deutlich eingerahmt von der Fortsetzung des östlichen Roten Meer-Bruches und von der Fortsetzung der Nilbrüche Keneh-Assiut. Es scheint aber, dass diese Bruchrichtungen auch im Bau der Inseln der südlichen Aegaeis eine Rolle gespielt haben, wenn man die SO-NW-Brüche auf Rhodos und die fast N-S gerichteten Brüche auf Kreta, mit ihren transversalen Verschiebungen der Schollen, betrachtet.

Als Ausgangspunkt kommen drei Linien in Frage: der östliche Rote Meer-Bruch, der nach Rhodos und der Westküste Kleinasiens hinüberzieht und den Sieberg als den *Levantinischen Bruch* bezeichnet hat. Ferner der Westbruch des Roten Meeres, der nach Kreta und dem Golf von Korinth fortsetzt und den Sieberg den *Aegaeischen Bruch* nennt und schliesslich die Fortsetzung der Nilbrüche, die am Westrand Moreas vorbei und durch das Jonische Meer nach Apulien zieht; Sieberg nannte sie den *Jonischen Bruch*. Diese drei Bruchlinien haben die Gestalt des Aegäischen und Adriatischen Meres und der Balkan- und z.T. die Appenninhalbinsel geschaffen. Besonders an dem steilen Abbruch am Rand der Jonischen Inseln, an der Westküste Kleinasiens, in der Gestaltung des Kykladen Meeres und der Halbinsel Chalkidike macht sich ihr Einfluss stark bemerkbar, wenn auch eigentlicher Grabencharakter nicht mehr vorhanden ist. Der erythräische Graben zersplittert hier, wohl unter dem Einfluss der Hellenidenfaltung; seine randlichen Schollenbrüche trugen zum Einbruch des östlichen Mittelmeeres, des Vorlandes der dinarisch-taurischen Faltung, bei und die wahrscheinlich schon alte Anlage dieser Senke hat den Raum geliefert, in den die Dinaridenfaltung weit nach Süden vordringen konnte. Das junge Senkungsgebiet des Aegäischen Meeres, welches nicht breiter ist als der Graben des Roten Meeres, kann man aber in seiner heutigen Gestalt deshalb nicht mehr mit einer Grabensenkung vergleichen, weil er schon innerhalb des gefalteten Orogens liegt und weil das alte Zwischengebirge der Kykladen nur in Schollen geborsten, aber nicht ganz versunken ist.

Diese Brüche, die ihrer Anlage nach sicher weit älter sind, als die jetzigen jungen Schichten ihrer Randgebiete, haben ihren Einfluss noch weiter auf den Bau Mitteleuropas ausgeübt, wie man an den vielen SO-NW Brüchen sieht, die im mittleren Teil Europas bis zur Senke der Nordsee und bis zu den Vulkanen Islands eine Bedeutung besitzen. Die Bruchlinien, die am Roten Meere an der Bildung des grossen Zerrungsgrabens beteiligt sind und teilweise horizontale Verschiebungen (Blattverschiebungen) noch im Bereich der Griechischen Inseln zeigen, werden weiter im Norden zu

regionalen Leitlinien des Schollenbaues, ohne dass irgendwelche Grabensenkungen sich an ihnen wieder bemerkbar machen. Für die Frage der Grabentäler spielen sie daher nur eine nebensächliche Rolle; ebenso wie auch die Zerrungsbrüche des Roten Meeres und von Aden mit ihrer Breiten- und Tiefenausdehnung wohl ganz andere, tiefergreifende Einschnitte in die Erdrinde darstellen, die weder mit den bisher besprochenen Bruchzonen noch den südlich anschliesenden ostafrikanischen Gräben verglichen werden können.

V. Zusammenfassung.

Man kann deshalb wohl sagen, dass es keine einheitlich durchlaufenden Grabensysteme gibt, die ganze Kontinentalschollen durchsetzen, da sowohl die ostafrikanischen wie die syrischen Gräben und die Mittelmeer-Mjösenzone complexer Natur sind. Wie die Faltungszonen sich durch Anbau und Fortbau (Stille) ausgestalten und an einander knüpfen, so auch die Grabenzonen, für die vor allem die syrischen Gräben ein deutliches Beispiel sind. Aber auch innerhalb eines einheitlichen und echten Grabentales wechselt die Gestaltung der Randzonen, da die Randbrüche sowohl bei Horsten, wie Gräben selten auf weite Entfernung durchlaufen, sondern abspringen und an Parallelsprüngen dann fortsetzen.

Im Gegensatz zu den Faltengebieten, in welche die Grabenbrüche nicht eindringen, da sie bezeichnende Erscheinungen der Vorländer sind, zeigt es sich, dass die regionalen Bruchzonen einen konservativen Charakter haben, da ihre Anlage teilweise viel älter ist, als die junge Geschichte ihres jetzt noch erkennbaren Schichtenbaues. Trotzdem folgen sie immer der gleichen Richtung (alte Rheintalbrüche im Carbon; Südbrüche des Thüringer Waldes im Perm), da eine einmal vorhandene Kerbe immer wieder die Neigung zeigt aufzureissen. Wenn die jüngeren Brüche auch nicht genau den gleichen Weg einschlagen, so setzen sie doch die alte Anlage des Bruchsysteme durch Fortbau in der gleichen Richtung fort. In Faltengebieten sehen wir meist das Gegenteil, dass ein einmal gefaltetes Gebiet nur selten wieder neu belebt wird, sodern dem sich durch Anbau angliedernden jüngeren Faltungszug als konsolidierte Masse des Wiederstandes gegenüber steht.

Für die Entwicklung der Vorlandsgebiete und ihre Gestaltung durch den aus den Orogenen wirkenden Druck sind die Grabensenken, die wir sowohl im nördlichen (Rheintal) wie im südlichen Vorland (Syrien) des alpinen Orogens verglichen haben, daher von besonderer Bedeutung. Aber auch für den Verlauf der orogenen Leitlinien und die Analyse ihres verwickelten Entwicklungsganges sind die Bruchsysteme nicht minder wichtig als die Faltungsgebiete, denen gegenüber man sie in letzter Zeit vielfach vernachlässigt hat.

41. THE MAGDALENA VALLEY, COLOMBIA, SOUTH AMERICA.

BY

J. V. HARRISON.

The following remarks on the Magdalena Valley and its environs are a result of a reconnaissance on behalf of the D'Arcy Exploration Company conducted in 1927 under the direction of PROFFESSOR HUGO DE BÖCKH.

The writer is indebted to the Company for permission to take part in this discussion and to his chief, PROFESSOR DE BÖCKH and colleague MR. F. D. S. RICHARDSON of whose work and report free use has been made in preparing this contibution.

The writer made journeys on both sides of the Valley between El Banco and Girardot and had the opportunity to fly over part of it on two occasions.

GEOGRAPHY.

The Upper Magdalena Valley is a trough like depression or Graben in which the Magdalena River flows, from Natagaima 3°37'N. 75°7'W. to El Banco 0°N. 74°W., a distance of about 300 miles.

Towards the north the western wall is lowered and eventually broken so that at El Banco the river leaves the line of the N-S trench and flows westward for about 60 miles. It then flows north again following the line produced by the extension of the Cauca Valley northwards to the sea.

A continuation of the north-south ditch to the north of El Banco occurs and is occupied by the River Ceasar, a tributary of the Magdalena. With this extension the total length of the trough is about 400 miles and its width of the order of 40 miles. Its behaviour further to the north is not known.

The thickness of the sediments lying upon the faulted floor of the trough to river level is not known, but from the present river level the walls of the trench usually rise as much as 4,000-5,000 feet to the edge of the bordering highland on both sides of the valley. Volcanoes and ranges rise to an altitude of more than 12,000 feet above the river level in some places.

The walls of the trench are not sheer but go up in a series of steps, well seen on both banks east and west of Cambao, but the impression left by the whole feature is that of a steep walled valley with a wide flat bottom. The line of the walls is not straight but determined by reticulate faults running N10-20E, N.E. and E. which have produced blocks.

It is a series of the E.-W. faults which have produced the break near El Banco which the river now follows. If the Magdalena Valley could be flooded to a depth of about five hundred feet the appearance of its northern end would recall the northern end of the Red Sea on a small scale.

The River Ceasar Valley would be the equivalent of the Gulf of Akaba and the lower Magdalena Valley the Gulf of Suez, whilst the Sierra de Santa Marta would represent Sinai Peninsula between them. The comparison is not absolute, for the Sierra de Santa Marta seems to be a continuation of the Cordillera Central which forms the western margin along the greatest part of the valley.

North of Honda the floor of the trench forms the flood plain of the river. There are many bifurcations of the river into groups of channels, and sediment is being deposited in many backwaters. The country is swampy and thickly covered by forests and jungle. Numerous relics of a terrace 150 feet above the present river level occur in this region and occasional remains of a 250 ft. terrace have been found to the east of Puerto Berrio. At Honda rapids have been formed by a fan deposited from the turbulent snow fed mountain stream of Maraquita blocking the main river and above this point it flows in a trench cut through the tuffs and terraces of the upper part of the valley. From here southwards the country is scrub covered and jungle no longer obscures the geology. Below Honda the hot climate is made unpleasant by the great humidity, whilst above Honda things are much more agreeable, the atmosphere being drier. The lower part is uninhabited except along the actual river banks, whilst above Honda the country supports a sparse population at a distance from the river.

The tributaries of the Magdalena from Girardot northwards are turbulent streams until they reach the Valley floor when they often lose their identity in the swamps and lagoons.

Geology.

Colombia is formed of two major geographical divisions.

1. The Llanos, or great plains, in the East.
2. The Cordillera Region in the West.

The Cordillera Region comprises four high mountain groups separated from one another by three low lying troughs filled with Tertiary Deposits. The subdivisions from east to west are:—

a. The Eastern Cordillera.
b. The Valley of the Magdalena River.
c. The Central Cordillera.
d. The Valley of the River Cauca.
e. The Western Cordillera.
f. The Valleys of the San Juan and Atrato Rivers.
g. The Coastal Range or Cordillera de Banda.

Then comes the Pacific Ocean.

Only the geology of the first three of these subdivisions need be considered here.

The Eastern Cordillera is a zone of strong folding and overthrusting towards the east in which the principal movements occurred in late Cretaceous times. Post Cretaceous faulting occurred and consequently strong erosion ensued. A new cycle of sedimentation then set in probably beginning in the Upper Eocene. Further movements occurred later which caused folding and faulting, but, so far as is known, did not cause overthrusting. The western limit of the unit is determined by extensive block and step faulting. Towards Natagaima in the south it is cut off by a system of faults striking N.E.-S.W. To the north it seems to divide, one part curving into the east-west striking mountains of northern Venezuela, while the other runs on into the north south range of the Sierra de Perija.

The Magdalena Valley is a big trough bounded by a reticulation of faults. It broke down during early Tertiary times and in it Tertiary sediments occur. The earlier of these are folded and intensely faulted. The faults were initiated in early Tertiary times, but faulting and sedimentation have continued together until late Tertiary.

The Central Cordillera is little known but pre Cretaceous sediments and abyssal, hypabyssal and eruptive rocks make up a considerable part of this unit, which was less disturbed in Laramide times than the Eastern Cordillera.

To describe the stratigraphy and structure of these units in greater detail it may be said that the Eastern Cordillera is made up of an eastern part in which thrusting occurs, and a western part where dysharmonic folds can be observed. The former consists of a complex of several geanticlinals with crystalline and pre-Cretaceous rocks in their cores. Dr. de Böckh and Mr. F. D. S. Richardson have observed granite thrust over Cretaceous near Pamplona which confirms a section published by Hettner and Linck in 1888.[1]

[1]) Beiträge zur Geologie und Petrographie der kolombianischen Anden. Zeitschrift der deutschen Geol. Gesellschaft. Vol. XL.

The pre-Cretaceous rocks occurring are of two types:—

(a) An upper part consisting of fluvatile beds, usually red or greenish in colour composed of granitic and schistose material, and (b) a lower part consisting of normal marine sediments. Limestones and shales from (b) have yielded Devonian and Carboniferous fossils, as mentioned by LIDDLE[2] from the Sierra de Perija and by STUTZER[3] from Cachala, N.E. of Bogotà, respectively.

The (a) series has not yielded fossils. It is sometimes of the order of 15,000 feet thick. PROFFESSOR DE BÖCKH found quartz porphyry associated with them near Pie de Cuesta de Bucaramanga and elsewhere the conglomeratic beds of the series contain pebbles of quartz porphyrites. Beds of the middle Cretaceous transgress over steeply dipping red beds of (a) series a few miles west of Sogamosa. Although salt has not been seen exposed in outcrops of this coloured group, salt plugs occur around Bogota at Zipaquire, Nemocon and Sesquile. In all of these the salt comes from below the lower Cretaceous shales and may therefore be derived from concealed deposits associated with this coloured series.

The Cretaceous beds in this eastern part of the Eastern Cordillera form the cover of various folds. They are composed of a sandy series with coals above, and of fossiliferous limestones and dark shales below.

In the latter or western part of the Eastern Cordillera the Cretaceous rocks are widely distributed, but because dysharmonic folding and block faulting are usual a reliable section from top to bottom has not yet been found. Near Alban between Bogota and Cambao the following section was worked out, it being a comparatively undisturbed one:—

ca.	1,000 feet.	Coal Group; with reddish arenaceous beds on top.
ca.	1,000 feet.	Guadalope Grits; the basal part sometimes represented by sandy calcareous marls and limestone
ca.	700 feet.	Chert Group; with many foraminifera. Dark shales and mudstones with limestone beds. Fish scales and bones and thin sandstone with vivianite.

Spirifer Arenosus Conrad., Chonetes sp., Retzia wardiana Hartt, Spirifer pedroanus Hartt., Leptaena rhomboidalis (Wilckens), Syringopora sp., Anoplotheca (Leptocoelia) flabellites Conrad, Fenestella sp., Stropheodonta and cf. Phacopsrana (Green).

[2]) R. A. LIDDLE. Tectonic of the Maracaibo Basin, Venezuela Bull. Assoc. Petroleum Geologists, Vol. XI. 1927.

Spirifer, Productus and crinoids in limestones.

Cordaites, Neuropteris and Sphenophyllum in the sandstones.

[3]) STUTZER. Beiträge zur Geologie der Kolumbianischen Ostkordillere in der naheren und weiteren Umgegend von Bogota.

Neues Jahrb. f. Min. Geol. and Pal. Beilage Band LVII.

ca. 1,600 feet. Black Shales containing marcasite nodules with ammonites
Dark shales with sandstones.
Shales with marcasite concretions and many inoceramus and ammonites.

The underlying part of the section is very disturbed and has not been worked out. Up to the Chert Group the strata have been called the Villeta Beds from which Eugster collected ammonites, afterwards determined by PROFESSOR COLLETT [1] as of Barremian and Aptian age. The Barremian forms are Pulchellia, Leptoceras, Hamites and Haplites; and the Aptian ones Douvilleiceras and Parahoplites. Middle Cretaceous forms were determined by STEINMANN,[2] viz. Schloenbachia acutocarinata Shum., S. Reissi d'Orb., and Acanthoceras Lyelli d'Orb. These are found in equivalents of the Chert Group. This group varies from dark bedded cherts full of foraminifera to a series of hard marls, dark shales and sandstones with abundant fish scales. The Guadaloupe Series is normally composed of whitish grits, often pebbly and containing black shales in places. The Coal Group rests conformally upon the Guadaloupe grits. It is composed of coarse thick bedded yellowish sandstones in the lowest parts passing to fine white sandstones with interbedded coals in the middle. In the higher parts red and grey shales occur with sandstones and silts, which have a similar aspect to some found in the lower part of the Tertiaries. Each of the Groups vary considerably laterally.

No rocks definitely known to be Tertiary have been found in the western part of Eastern Cordillera, but there is so much block faulting that they may yet be found in small faulted down patches. The principal faults trend N.10-15E., but N.E. striking faults are also common and important.

THE MAGDALENA VALLEY.

The Tertiary beds occurring on the fringe of the Eastern Cordillera are separated from the Cretaceous by a very disturbed zone in which normal faults are common. Hence they belong to the Graben even though topographically they occur on the eastern edge high above the floor of the Magdalena Trench.

A complicated but fairly continuous section is exposed between La Sierra and Cambao on the road from Bogota to Cambao. The lower Cretaceous is faulted against Tertiaries, which are greatly disturbed so that the relationship of outcropping red shales and conglomerates full of chert

[1]) W. L. COLLET Sur quelques Ammonites du Barremien de Colombia. Eclogae geol Hélvetiae Vol. XVIII, 1924.

[2]) G. STEINMANN. Mittheilung über die geol Altersbestimmung der Kolumbischen Kreideschichten, in Hettner, Kordillera Von Bogota 1892.

and hard sandstone pebbles is not clear. Immediately west of this zone, and a little south of Guaduas a sharp syncline occurs made up as follows:—

	5.	Olive Shale Group; Shales, silt and standstones with plant remains and shell beds.
ca. 1,800 ft.	4.	Upper Coloured Group; Red and purple sandy clays with subordinate sandstones.
ca. 800 ft.	3.	Quartz grits and conglomerate.
ca. 1,500 ft.	2.	Lower coloured Group; Red and purple sandy marls and clays with green flysch-like sandstones.
ca. 1,800 ft.	1.	Massive conglomerates and sandstones passing up into massive marly sandstones and sandy marls.

Although these beds can be distinguished on both flanks of the syncline they are known to vary considerably in the same fold along the strike, which makes grouping over a distance most difficult.

To the west of the syncline strong step faults occur and the massive conglomerate with some associated coloured beds recur in the great fault bounded escarpments. Just before reaching the river, on the floor of the trench near Cambao, a faulted block of conglomerates containing pebbles of andesite and tuffaceous material occurs. Similar rocks are found at intervals across the valley floor to its western limit. In contrast to the older beds those which are tuffaceous are only gently tilted except near the lines of faulting, where steep beds have been seen. About 20 miles north of Cambao and 1 mile east of Honda two groups of folded sediments outcrop. The lower group consists of sandstones, pebbly sandstones and conglomerates with interbedded red and green sandy marls containing some veins of selenite. Its pebbles are derived largely from the older rocks such as granites, schists and pre-Cretaceous beds. Scarce Cretaceous pebbles have also been found and there are occasional fragments of silicified wood. The upper division consists largely of conglomerates containing porphyrite pebbles.

Between Girardot, Tocaima and Fusagasuga the Tertiaries occurring low in the Valley are found lying in contact with faulted blocks of Cretaceous rocks. On the Western side of the Valley near Gualanday Station a steep fold exposes a section, reported by Messrs. F. D. S. Richardson and H. K. Long as follows:—

5. Massive conglomerate; with many Cretaceous pebbles.
4. Red clays with sandstones and some conglomerates.
3. Hard mottled sandstones with some conglomerates.
2. Red, purple and grey soft clays and sandy clays with selenite and a few sandstones and fine congl. bands.
1. Greenish-blue sandy marls with marcasite and selenite, with thick white sandstones and lignitic sandstones.

About 200 miles further north a good section occurs along the Lebrija River from Puerto Santos eastwards to the foot of the Eastern Cordillera:—

Group C (locally called Puerto Santos Beds.)

ca. 1,300 ft.	(7)	False-bedded, pale green and white pebbly grit; poorly consolidated.
ca. 1,500 ft.	(6)	Granite-conglomerate with many interbedded red marls and clays.
1,500 ft.	(5)	Coarse granite conglomerates.
ca. 1,500 ft.	(4)	Schist and hornfels conglomerate.
1,800 ft.	(3)	Quartzite, quartz porphyry and pre Cretaceous Red Bed conglomerates with some mottled clay beds.
800 ft.	(2)	Quartzite chert limestone and red sandstone conglomerate.
900 ft.	(1)	Mottled purple and brown silts with thin chert conglomerate.

Then comes a short alluvium-covered part in which faults may be obscured.

Group B (locally called Chuspas Beds.)

ca. 1,500 ft.	(3)	Red and purple mottled clays and marls.
ca. 1,000 ft.	(2)	White and brown quartz sandstones with thin detrital coals, thin shell beds and small marcasite nodules.
ca. 2,000 ft.	(1)	Flysch-like greenish sandstones, lignitic sandstones and grits.

Group A appears to lie conformally below group B.

Group A (locally called La Paz Beds.)

1,300 ft.	(3)	Sandstones with shaly layers and carbonised wood.
900 ft.	(2)	Gritty sandstones with coarse pebbly beds and coal pebbles.
800 ft.	(1)	Hard fine grained sandst. ripple marked, carbonised tree trunks. Coarse pebbly-beds and red mottled clays with interbedded pebbly grits.

FAULTED JUNCTION.

Much disturbed coal group of Cretaceous Age.

This section shows plainly the progress of Tertiary erosion which acted upon the Cretaceous after the breaking down commenced, resulting in the formation of the Graben. In the La Paz Formation (A) only debris from the uppermost or coal group of the Cretaceous is common with which tree trunks and well rounded quartz pebbles from the old land surface are mixed. After the very rapid erosion at the commencement of the cycle

of Tertiary deposition the quieter conditions occurred when the fine sands and clays of the Chuspas were formed in lacustrine conditions and with the occasional occurrence of shell banks. Then fresh breaking down occurred and a renewal of active erosion. This progressed rapidly and cut down through the adjoining geanticline from the Cretaceous shales and limestones, reaching stage by stage the early Mesozoics and its intrusive porphyrites, then the hornfels sheath of the granite and finally the granite core itself. The upper group (C) or the Puerto Santos beds are interpreted as the fan of a big Tertiary River, for such a great thickness is not usually found in other sections where this group is exposed. PROFFESSOR DE BÖCKH points out that the faulting which probably exists between the groups B and C in this section may be very important and that an alternative explanation for the section may be that Group C is a tectonically brought above B and may be a local variation of Group A.

Between this section and the southerly ones already described a faulted section east of Puerto Berrio shows a sequence:—

c. Grits with some conglomerates.
b. Red and grey marls with subordinate sands.
a. Hard grits and conglomerates.

Apart from one exposure near the Magdalena east of Puerto Berrio where group (C) contains andesitic material, the folded beds do not contain young igneous rocks. This exceptional case is recorded, but from its position, and as exposures are not good, it is possible that admixture from the overlying andesitic bearing terrace gravels may have "salted" the section.

The change in the topography around Honda which has been already described is due to the thick deposits of late Tertiary tuffs and tuffaceous sandstones. These have issued principally from the great volcanoes which occur from about lat. 5N southwards, on the western side of the Valley.

The correlation of the fresh water Tertiary deposits occurring in the Magdalena Valley is a difficult task. The vegetation is dense and exposures generally poor. Each section is through part of a fan of a different Tertiary River which discharged into the trench. Fossils are scarce and of small stratigraphical value as they are fresh water forms. The strata are sometimes tightly folded, and finally faults break up the folds. The task is made still more difficult by a profusion of place names which have been applied to beds in isolated outcrops. However what is known is that wherever a normal series has been observed there is in the basal part a coarse conglomerate group.

No marine Tertiary fossils have been found in the Magdalena Valley Graben which extends south from El Banco, but at Toluviejo on the northern

extension of the Cauca Valley trough WERENFELS[6] found Helicolepidina and Lepidocyclinas in white limestones near the base of a marine Tertiary Series. Consequently Upper Eocene or Lower Oligocene seas were able to invade the next Graben to the West. This scanty palaeontological evidence supports the tectonic evidence already brought forward that the Tertiary basal Conglomerate group may be about Upper Eocene in age. This implies the assumption that the breaking down and formation of the three great Colombian Graben were approximately contemporaneous.

The faulting affecting the beds in the Magdalena Valley is [7]along three major directions, N.10-15E., N.E. and E. These directions have been found in the course of detailed survey, but can be readily distinguished by the conduct of the river itself between Honda and Girardot where the sharp turns in the river are principally controlled by fault lines. The faulting has continued from early to late Tertiary, for the coal group of the Cretaceous on the fringe of the Graben is much more faulted than the subsequent beds, but PROFESSOR DE BÖCKH discovered that even the gently titled andesitic tuffs are faulted. The tuffs in places are found to transgress and obscure faults which have stepped down blocks of older rocks. And so faulting has been active at different times during the settling of the valley floor.

The western side of the Graben is formed by the block-faulted edge of the Central Cordillera. Peneplained blocks of pre-Cretaceous rocks form the gently tilted plateaux which are conspicuous in the landscape on the western side of the river from Puerto Wilches to Girardot. The character and relations of some of these blocks have been seen in several sections.

Along the railway line from Puerto Berrio to Medellin contact metamorphosed limestones and hornfels outcrops near Melena. Patches of late Tertiary andesitic conglomerate grits, sandstones and clays with a little silicified wood occur resting flat upon the older rocks, which are tightly folded quartzites and shales penetrated by granitic rocks. Near Cristalina, about 1 kilometer from the railway, the shales contain graptolites which DR. G. L. ELLES has determined. Didymograptus extensus Hall, D. nitidus Hall, D. gibberulus Nich. and D. hirundo Salt. occur, and these are placed in the Arenig, at the base of the Ordovician. Further west more intrusions occur, and then a series of dark shales with obscure plant remains. These are followed by phyllites and schists greatly intruded by thin aplite veins and penetrated and metamorphosed by a series of plutonic and hypabyssal

[6]) A. WERENFELS. A stratigraphical section through the Tertiary of Toluviejo, Colombia.
Eclogae geól. Helvetiae. Vol. XX. 1926

[7]) The N10-15E direction is the most important along which faulting occurred, but there does not appear to be any great difference in age between faults occurring in the different directions.

rocks including granites, diorites, syenites and kersantites. The crest of the Cordillera on this line is an old peneplain about 6,000 feet above sea level which is greatly eroded by streams and rivers which are discharging into the Magdalena.

A mile to the west of Nare the eastern edge of a fault-block occurs, made up of much disturbed and intruded shales, slates and grits.

About 10 miles west of Buena Vista shales and quartzites are intruded by granites; while about 12 miles west of La Dorada shales, schists and quartzites are intruded by granites and overlapped by andesitic tuffs. Near Victoria, S.W. of La Dorada, quartzites, schists, and contact metamorphosed limestones have been found intruded by granites and syenites. Near Victoria, where block faulting is conspicuous and where the valley side is steep, lava flows from the Tertiary volcanoes are seen. Between Ambalena and Ibague a block in which intruded granite is preserved is dropped down low and appears below the andesitic tuffs. Near Ibague altered sediments are intruded by granite and Tolima, an active volcano, rises as a great glacier clad peak above the valley on its western side. The cones of other volcanoes are visible, on the eastern edge of the Central Cordillera as far north as Puerto Wilches, but there they are no longer active.

Grosse has shown that in the western part of the Central Cordillera volcanic rocks of several ages from palaeozoic to recent occur, and it is highly probable that the igneous complex found in the eastern part of the Central Cordillera has as complicated a history.

Conclusions.

Some of the evidence regarding the stratigraphy and structure of the Magdalena Valley and its walls has been given above. It has been shown that there is a trench, at least 400 miles long, and about 40 miles wide, which has a depth of more than 4,000 feet, and that it broke down in early Tertiary times, probably in the Lower Eocene. Volcanic activity has been and is prevalent along much of its western edge. The position of this structure is behind a range of fold mountains and on the edge of the Median Mass (Hinterland or Zwischengebirge.)

It is known that two other parallel trenches occur in Colombia, but details regarding them are scarcer. They are also the result of trough faulting. There are tertiary sediments in them and volcanic activity along their flanks. They are probably all similar in their origin and of about the same age.

The cause suggested is that after the formation of the great Laramian ranges of north South America instability was wide spread and in the country

behind the fold mountains tensional stresses set in. The stresses imposed on the earth's surface were greater than the material composing it could stand, and to relieve the strain great fractures developed and vertical movements of strips of the earth's crust occurred along these. Relief from tensional forces would be at once obtained in this way as a down faulted strip subtends a greater angle at the earth's centre than it did before being dropped down

42. MAP OF THE PRE-PLEISTOCENE SUBSOIL OF SOUTH-LIMBURG (the Netherlands)

BY

J. J. PANNEKOEK VAN RHEDEN

By permission of the Director of the Dutch Geological Survey, Dr. P. TESCH, I am enabled to submit a map of the pre-pleistocene subsoil of southern Limburg.

This map will be published shortly by the "Geologisch Bureau voor het Nederlandsche Myngebied" in Heerlen, together with "Ryks Geologische Dienst" in Haarlem.

It has been composed by Dr. W. J. JONGMANS and Mr. F. H. VAN RUMMELEN on behalf of the Geologisch Bureau voor het Nederl. Myngebied and myself on behalf of Ryks Geologische Dienst.

The area represented on the map accompanying this paper is situated on the South-western margin of the great rift valley the Lower Rhenane Plain (Niederrheinische Tiefebene).

The right margin of the main valley runs about S-N, the left margin about S.E.-N.W.

This great rift valley through which the river Rhine takes its course after leaving the Rheinische Schiefergebirge, is subdivided by numerous faults into a number of secundary higher and lower blocks, whose general trend is S.E.-N.W. As a rule the amount of throw between the blocks increases towards the N.W., and the surface of the blocks slopes in the same direction. Not only is this the case with the present surface but also the tertiary and older sediments show a slope to the N.W. that increases in amount, as we descend to older and older strata.

Leaving out all detail the sequence of events was as follows: After deposition of the Upper Carboniferous the region was subjected to folding which was most pronounced in the Permian, but probably started already during the Upper Carboniferous. The folding was strongest in the S.E. becoming less and less marked towards the N.W.

These Hercynian mountains were reduced to a peneplain. Now faulting set in, together with a slow, often interrupted, but ever returning tilting towards the N.W. The sea transgressed and regressed many times and the rivers deposited great masses of sediments in the troughs. This faulting, that has lasted during the whole mesozoic and cainozoic periods, is clearly observable in the early Pleistocene and seems still to be going on (tectonic earthquakes-chiefly along Feldbiss, f.i. that of Herzogenrath of 1873 and 1877).

A short synopsis of the stratigraphical sequence is given below in tabulated form.

The general features of this whole region, that were exposed above, are also the leading features of Southern Limburg.

Profile I shows in the S.E. the strongly folded and overthrust Devonian, Lower and Upper Carboniferous. Towards the N.W. the folding dies out. At the same time the younger subdivisions of the Coal Measures make their appearance, increasing the tōtal thickness of the Upper Carboniferous up to 3,500 m. The slope towards the N.W. of the upper surface of the palaeozoic rocks is pronounced. The Oligocene and Mio-Pliocene slope in the same direction, but not so strongly.

Profile II is taken more to the N.E. Excepting the Senonian, all strata are thicker here than in Profile I, the older ones having suffered less from erosion, the younger ones having been laid down in greater thickness. The saddle in the S.E. is clearly visible. The folding dies out to the N.W., and the Carboniferous increases in thickness in the same direction. In the overlying Triassic, Senonian, Oligocene and Mio-Pliocene the increase in thickness towards the N.W. and the decrease of slope in the younger layers is marked.

Though Profiles I and II show many common features there is one curious difference which will be explained later on: in Prof. I the Senonian outlasts the Oligocene (partly due to subsequent denudation) and reaches a thickness of 200 m.

In Profile II again the Senonian is overlapped by the tertiary and is reduced to a thin layer.

Profile III is a cross profile. In the S.W. is the Massive of Brabant. The Carboniferous Limestone was actually reached here in borings. The Upper Carboniferous, the Oligocene and Mio-Pliocene increase in thickness, as we proceed to the N.E., whereas the Senonian thins out.

On Profile IV taken farther to the S.E. the total downthrow beyond the Feldbiss has diminished and the downfaulted formations are accordingly thinner. In the S.W. the Senonian is well developed, whereas in the N.E. it has completely wedged out.

The saddle in the Carboniferous is cut obliquely by this profile.

Profile V taken in the N.W. corner shows the increase of the Triassic and Tertiary towards the N.E., but the Senonian beyond the Feldbiss is much thinner.

The reduced thickness of the Carboniferous in the easternmost block seems to be due to stronger denudation.

The discrepancy in behaviour between the Senonian and the other formations that we have met in the profiles, the one thinning out when the others are thickest, is explained by assuming an oscillating movement of the fault blocks.

The N.E. strip of South Limburg would have been lower in carboniferous, triassic and tertiary time, but higher during the senonian transgression and just after, thereby receiving only a thin cap of cretaceous sediments, and same being subjected to stronger denudation.

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SECTION VII.

GENERAL.

43. THE NORITE OF SIERRA LEONE, BRITISH WEST AFRICA.

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WITH CHEMICAL ANALYSES

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CONTENTS.

I. Introduction.

The geology of the Sierra Leone Peninsula was described by Dr. F. Dixey[1] in 1922. He showed that the norite exposed around Freetown, which had been briefly described by Gürich[2] in 1887 and by Prof. Shand[3] in 1918, was only one end of a huge noritic complex which made up the whole of the mountain mass of the Colony of Sierra Leone together with the Banana Islands. The main intrusion according to Dixey is a well banded relatively fine grained olivine norite intruded in the form of a huge stock which was invaded in succession by (1) coarser grained norites, (2) norite pegmatite, (3) beerbachites, (4) norite-aplite, and (5) dolerites. Dixey demonstrated the corrosion and assimilation of the older banded norite by the younger intrusions and described an interesting series of mineral intergrowths.

Unless otherwise stated all the chemical analyses given in this paper, and with one exception all the calculations of norms, were made by Dr. Harwood.

The writer is indebted to Mr. J. D. Pollett, A.R.S.M., for assistance in the field during May, 1929.

II. Size and Form of the Intrusion.

The intrusion gives rise to a highly dissected mountain mass rising abruptly from the sea to an elevation of nearly 3,000 feet. A large part of the area is thickly forested; away from the coast line and the roads around the foot of the hills from Freetown to Waterloo and Kent, villages and tracks are few and far between.

The exposed portion of the main intrusion is elongated in a N.W.—S.E. direction,—parallel to the coast line—is about 25 miles long, has a maximum width of between 8 and 9 miles, and covers an area of about 170 square miles. On the landward side, the railway line from Freetown to Waterloo and the road from Waterloo to Tumbu, mark approximately the limit of the exposures (see Map.) On this side—and in places on the seaward side—the rocks are covered up by sands and clays of Pleistocene? age.

Between the main intrusion and the highly metamorphosed garnet and hornblende gneisses to the east near Bradford and Rotifunk two masses of

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1. "The Norite of Sierra Leone," Q.J.G.S., Vol. LXXVIII, Part 4 (1922.)
2. "Olivingabbro von Freetown (Sierra Leone)." Deutsch. Geol. Gesellsch., Vol. XXXIX, p. 108.
3. "The Norite of Sierra Leone," Geol. Mag. 1918, p. 21.

gabbro appear above the capping of sands and clays. The first intrusion consists of hornblende gabbro and is situated at Songo Town, 10 miles east of Waterloo. It is roughly half a mile long by a quarter of a mile wide. The second intrusion consists of olivine norite and is situated near the Masanki Oil Plantation, Mabang. It is possible that the main intrusion continues beneath the sedimentary capping as far as Songo Town and Mabang, but it seems more likely that the intrusions at these places are "satellites" of the main mass. Dykes of dolerite of somewhat similar composition traverse the garnet and hornblende gneisses near Rotifunk.

The rocks which originally formed the roof of the main intrusion have been removed by erosion and the rocks forming the floor of the mass are obscured by sands and clays. Consequently, the form of the intrusion cannot be directly determined. DIXEY[4] has stated that the norite of Sierra Leone is remarkable in that it occurs as stock which shows neither a marginal nor a stratiform structure, and PROF. S. J. SHAND[5] states "This great intrusion must be regarded as a true batholith." These conclusions are not supported by the observations of the present writer, and, for the following reasons, he believes that the intrusion is in the form of a large basin-shaped sheet, portion of which has been cut off on the seaward side.

(1) The rocks exhibit a marked banding which on weathered surfaces appears as alternating parallel ridges and grooves resembling the stratification of a sedimentary rock (see Plate VII, Fig. 13.) On fresh surfaces the banding is indicated by alternating dark and light coloured bands and streaks due to the concentration of femic and salic minerals respectively, by a well defined fluxion structure shown by the parallel orientation of prisms of plagioclase, and by variation in the granularity of the rocks. In places platy jointing occurs parallel to the banding. The strike of the banding swings round gradually from 80° mag. at the S.W. end of the Banana Islands near the village of Rickett, to north and south near York, and to 260°—265° mag. at Aberdeen (see Map.) The banding dips regularly inwards, at an angle averaging between 25° and 30°, towards a point situated out to sea to the west of York. GROUT[6] gives a number of examples of basic masses in which the banding is parallel to the upper and lower surfaces of the intrusions and concludes that "These results are sufficiently uniform—only one apparent exception—to warrant the assumption that in a large way the fluxion and banded structures, as well as sheet jointing (when not referable to surface weathering) may be a guide to the position

4. Op. cit. p. 302.
5. The Eruptive Rocks, p. 218.
6. F. GROUT—Journal of Geology—Vol. 26, 1918, p. 451.

of the boundaries of igneous masses and, therefore, of great value in mapping igneous forms."

(2) The Sierra Leone intrusion shows a definite stratified character and thick sheets of rock of the same composition, e.g. troctolite, and narrower layers and bands of anorthosite, ilmenite and titanomagnetite, have been traced for considerable distances and found to conform closely in strike and dip with the banding.

(3) The concentric and radial arrangements of most of the dolerite and beerbachite dykes and micropegmatite veins—

(a) trending parallel to, and dipping at right angles to, the synclinal banding of the intrusion, and

(b) trending at right angles to the banding and dipping near vertical—agree with the direction of the tension fissures developed in a laccolith, the central portion of which has been depressed, forming a basin shaped sheet.

It is probable, as has been suggested by Dixey,[7] that the Sierra Leone gabbro-mass was injected along a line of crustal weakness. Several other intrusions of a similar type occur, over a length of more than 150 miles, in a more or less straight line, close to and roughly parallel to the coast line, from Liberia to French Guinea.[8] Swarms of dolerite dykes having the same trend, occur in Sierra Leone on approximately the same line as these intrusions of gabbro and allied rocks.

III. Petrology.

(1) *General Description.*

The various rocks have not yet been mapped in detail, but, viewed broadly, the general sequence of rocks in the Freetown, Waterloo and York districts is as follows:—

The lower part of the exposed portion of the intrusion consists mainly of banded olivine rich troctolite with a layer not far from the base of anorthosite and anorthositic gabbro. Associated with the latter rocks are narrow bands of ilmenite and titanomagnetite and some beerbachite. Locally, small masses of picrite and peridotite are found in the troctolites.

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7. Op. cit. p. 305.

8. The gabbros and peridotites described by A. Lacroix from the massif of Kakoulima, French Guinea, closely resemble the Sierra Leone rocks. See C.R. Acad. Sci. Paris. Vol. CXL. p. 410, 1905.

Banded gabbro and olivine gabbro—including norite and olivine norite—are prominent in the central portion of the intrusion, and trocolites are not abundant. A large lenticular sheet-like mass—in places as much as 700 feet thick—of coarse grained anorthosite and anorthositic gabbro occurs near York Pass. Small lenticular masses of ilmenite occur in the anorthosite.

In the upper portion the rocks are mainly banded gabbros and norites—with subordinate olivine gabbros, olivine norites, and troctolites.

Some of the coarser grained, poorly banded rocks are intrusive into the finer grained banded rocks. Most of the intrusions are concordant, and they are relatively of small volume compared with the banded rocks.

After these rocks were cooled numerous dykes of dolerite and beerbachite, and rarer ones of micropegmatite, were injected into them. Most of these dykes fill tension joints formed by the sagging of the central portion of the intrusion.

Considering the mass as a whole olivine gabbro (including olivine norite and troctolite) is the most abundant rock. Ordinary gabbros and norites are next in order of importance. These are followed by anorthosite and anorthositic gabbro, and small volumes of peridotite and other rocks.

Plagioclase—most of it is near $Ab_1\ An_2$—is the most abundant mineral and makes up nearly 50% of the average rock. Olivine—an iron rich variety—and pyroxene occur in about equal amounts. Monoclinic pyroxene—usually schillerised smoky diallage—is in excess of the orthorhombic pyroxene which is chiefly hypersthene. Titanomognetite is generally an accessory mineral, but, locally, it becomes an important constituent of the rocks. Biotite, orthoclase, quartz, apatite and green hornblende are present in small quantities in certain specimens. Some of the last named minerals are much more prominent in the later dyke rocks. Sulphides are rare.

All the rocks are remarkably fresh and have suffered only slight crushing.

(2) *Troctolites.*

Olivine rich troctolites are well developed around the margin of the intrusion, and particularly between Freetown and Waterloo. Near Freetown they form a thick sheet upwards of 500 feet thick. Other layers of troctolite occur higher up in the intrusion.

The troctolites are leucocratic or mesocratic medium grained well banded rocks, composed of green olivine, which weathers to a reddish brown colour, and pale grey plagioclase. The relative proportions of olivine and felspar vary considerably, but in the average rock olivine is slightly in excess of the felspar. The average specific gravity of four specimens is 3.16.

Thin sections consist of rounded grains of colourless olivine and prisms of slightly zoned basic labradorite—in sub-parallel arrangement. A little pyroxene—diallage and/or hypersthene—is present in many specimens and it often forms reaction rims around the olivine. Titanomagnetite is uncommon, but in places, e.g. at Aberdeen and Mt. Aureol, Freetown, bands of olivine and felspar rocks containing as much as 25% of titanomagnetite in disseminated grains, have been noted. Biotite is a rare constituent and when present, occurs for the most part as reaction rims, fringed by feathery growths of colourless pyroxene or zoisite, around grains of titanomagnetite.

The specimen analysed contains a little less olivine than the average troctolite of the intrusion. The norm shows that the rock consists of plagioclase (near Ab_{33} Or_{5}) and olivine containing nearly 40% Fe_2 SiO_4, in approximately equal amounts.

TABLE I.—CHEMICAL ANALYSES.

	304	393	290	259	286	344	A.
	%	%	%	%	%	%	%
SiO_2	51.67	50.58	49.52	44.45	40.24	37.83	38.32
AL_2O_3	26.31	16.88	12.81	14.45	1.50	2.28	2.66
Fe_2O_3	1.23	2.79	1.65	1.05	2.30	1.80	4.35
FeO	1.85	6.02	5.66	14.13	19.78	24.69	11.78
MgO	1.31	6.89	12.33	16.93	30.11	31.81	36.22
CaO	12.37	13.26	15.32	6.37	4.33	0.89	2.74
Na_2O	3.55	2.45	1.10	1.88	0.04	—	0.16
K_2O	0.40	0.13	0.14	0.34	0.06	—	0.06
H_2O+	0.50	0.40	0.55	0.35	0.51	0.09	
H_2O+	0.50	0.40	0.55	0.35	0.51	0.09	3.38
CO_2	0.18	0.05	0.16	—	0.63	—	
TiO_2	0.51	0.62	0.73	0.07	0.30	0.18	0.28
ZrO_2	nil.	nil.	nil.	—	nil.	—	
P_2O_5	nil.	tr.	tr.	—	tr.	—	
S	0.01	0.01	0.01	—	0.01	—	
MnO	0.04	0.15	0.15	0.17	0.32	—	
SrO	0.01	tr.	tr.	nil.	nil.	—	
BaO	tr.	tr.	nil.	nil.	nil.	—	
Li_2O	tr.	nil.	nil.	—	nil.	—	
V_2O_5	0.03	0.06	0.04	tr.	0.03	—	
Cr_2O_3	tr.	0.02	0.18	nil.	0.015	—	0.16
NiO	nil.	nil.	tr.	0.04	0.05	0.06	0.16
	100.10	100.42	100.41	100.32	100.41	99.74	100.18
Specific gravity	2.72	2.90	3.16	3.12	3.33	3.43	

NORMS.

		304 %	393 %	290 %	259 %	286 %
Quartz		1.99	0.28	—	—	—
Orthoclase		2.34	0.78	0.83	2.2	0.33
Albite		30.04	20.71	9.28	15.8	0.31
Anorthite		54.73	34.82	30.04	29.9	3.84
Diopside	Ca SiO_3	2.30	12.80	18.77	0.8	5.67
	Mg SiO_3	1.44	8.17	13.51	0.3	3.62
	Fe SiO_3	0.71	3.80	3.56	0.5	1.67
Hypersthene	Mg SiO_3	1.81	8.98	11.25	0.2	8.54
	Fe SiO_3	0.89	4.19	2.29	0.3	3.39
Olivine	Mg_2SiO_4	—	—	4.16	29.3	44.10
	Fe_2SiO_4	—	—	1.20	19.0	22.37
Magnetite		1.78	4.05	2.38	1.6	3.33
Ilmenite		0.97	1.17	1.38	0.1	0.56
Pyrite		0.02	0.02	0.02	—	0.02
Apatite		—	—	—	—	0.03
Calcite		0.41	0.11	0.36	—	1.43
Water		0.63	0.51	0.61	0.4	0.68
		100.06	100.39	100.32	100.4	100.35
		Labradorose	Auvergnose	Auvergnose		Kakoulimose

304—Anorthosite—Big water near York Pass Forest Guard Barracks.

393—Beerbachite—Near Lumley Road Station.

290—Olivine gabbro—Bangbahal to Toke by bush track at 2.2 miles.

259—Troctolite—Sugarloaf gap on track from Regent to Sussex—Analyst:- L. S. THEOBALD.

286—Hypersthene peridotite—Baw Baw to No. 2 at half a mile.

344—Dunite—Bura Town to Kent at 1¼ m. along shore.—Analyst:- L. S. THEOBALD.

A— Wehrlite from Kakoulima, French Guinea.—Analyst:- A. LACROIX ?

(3) *Gabbros and Norites.*

These are dark coloured fine to coarse grained rocks. The finer grained types are usually banded and many of the coarser grained rocks are spotted. The average specific gravity of four specimens of ordinary gabbro and norite is 3.01, and of three specimens of olivine gabbro 3.16.

In the normal gabbros and norites the plagioclase ranges in composition form labradorite to bytownite, but in some of the olivine gabbros it approaches anorthite in composition. The pyroxene is chiefly smoky diallage. When orthorhombic pyroxene is present it is usually hypersthene for the most part, but in some specimens bronzite and enstatite are more prominent.

The olivine is an iron rich variety similar to the olivine in the troctolites. The texture of the rocks is allotriomorphic to sub-ophitic.

A common feature of the rocks is the occurrence of reaction rims of hypersthene around grains of olivine (in some sections the hypersthene is coated with diallage), and of biotite and vermicular growths of colourless pyroxene? around grains of titanomagnetite (See Plate I, fig. 1, Plate II, Fig. 3 and Plate III, Fig. 6.) In specimens Nos. 358 and 366, of olivine norites from Samuel Town growths of greenish brown hornblende fringe and traverse the hypersthene.

The thin section of the specimen of olivine gabbro analysed (No. 290) consists of schillerised diallage, and slightly zoned plagioclase near anorthite, with a little olivine hypersthene and bronzite.

(4) *Anorthosite.*

A large lenticular sheet-like mass of anorthosite occurs near York Pass. Good exposures are to be seen in the Big Water between York Pass and York. The anorthosite is practically free from banding, and forms large tors and hummocky outcrops with a scaly and pitted surface. The rock is coarse grained and when fresh is dark grey in colour. Weathered specimens are light grey or white. In places, e.g. near the contact with the banded gabbros the anorthosite becomes richer in pyroxene and passes into anorthositic gabbro. Dykes of dolerite, beerbachite and micropegmatite cut the anorthosite, and a few small lenticular masses of ilmenite have been noted in the rock.

A thin section (No. 304) of anorthosite from the Big Water near York Pass Barracks* consists almost wholly of aggregates of allotriomorphic grains of basic labradorite near $Ab_1 An_2$ with a trace of interstitial pyroxene, ilmenite and corbonate. (Plate III, fig. 5). Abundant minute inclusions are present in the plagioclase. These give the dark colour to hand specimens of the rock. Some of the inclusions occurring in parallel lines of minute needles appear to be rutile. Numerous cracks containing a mineral which is apparently a zeolite traverse the felspars.

An analysis of the specimen closely resembles the average analysis of anorthosite given by Daly.[9]

Bands of anorthosite and anorthositic gabbro, associated with titaniferous iron ore and some beerbachite, form a well marked "horizon" in the lower part of the intrusion between Waterloo and Freetown. Thin bands and schlieren of anorthosite occur in many other places in the banded gabbros.

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* The Big Water is the right hand branch of the Whale River. The York Pass Forest barracks are situated on the road from York to Waterloo, on the York side of the pass.

[9]. R. A. Daly—Igneous Rocks and their Origin, 1914, p. 8.

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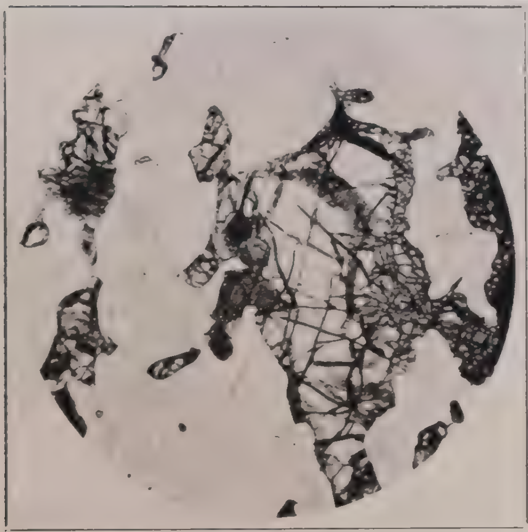

Fig. 1

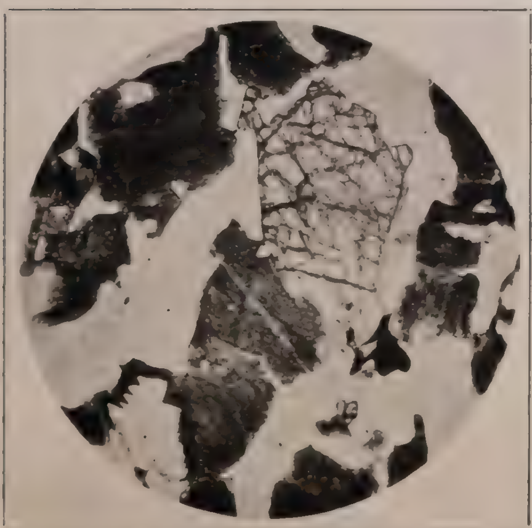

Fig. 2

PLATE I

Communication No. 43

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Fig. 3

Fig. 4.

PLATE II.

Communication No. 43

(5) *Peridotite and Dunite.*

Typical peridotites have been found in only a few places, and all the occurrences are of small size. Dunite is even less common.

The peridotite on the foreshore ½ m. on the No. 2 side of Baw Baw village is a concordant sheet, dipping to the S.W. at 20°, in banded troctolite. The rock is coarse grained and consists mainly of granular green olivine with large porphyritic schillerised crystals of black pyroxene. Poikilitic inclusions of olivine are common in the pyroxene. The Specific gravity of the rock, 3.43, is very high. A thin section is composed of aggregates of rounded grains of olivine with subordinate hypersthene and scanty interstitial plagioclase (anorthite) and odd grains of black iron oxide, biotite, rutile and chromite. The hypersthene is schillerised and wraps round the grains of olivine in poikilitic fashion. The olivine has an ill defined cleavage and it's sign is negative indicating an iron rich variety. This is confirmed by the high percentage of FeO in the rock and also by it's high specific gravity. Roughly parallel lines of minute acicular inclusions (rutile?) traverse the section.

Similar peridotite outcrops on the foreshore between Bura Town and Kent, at about 1¼ miles from Bura Town. The peridotite is intrusive in banded troctolite and tongues of peridotite cut across the banding of the troctolite. Small masses of dunite are associated with the peridotite.

Analysis are given in table I of the peridotite from near Baw Baw (No. 286) and of the dunite near Bura Town (No. 344). The most striking features revealed by the analyses and norms are the usually high percentages of FeO (19.8% and 24.7% respectively) in the rocks, and the high percentages of $Fe_2 SiO_4$ (about 35%) in the olivine. In these respects the rocks are intermediate in composition between the ordinary olivine rich peridotites and dunites [10] containing an olivine with between 8% and 12% $Fe_2 SiO_4$ and the hortonolite-dunites, the olivine of which contains about 50% $Fe_2 SiO_4$, from the Bushveld.

The very low percentages of water and CO_2 in the rocks indicate that they are practically free from serpentine and magnesite. A similar peridotite from between the York Pass Forest Baracks and Good Luck Hill, at an elevation of between 900 and 1000 feet above sea level, however, is in part largely replaced by magnesite and serpentine.

In some respects the peridotite from near Baw Baw resembles the wehrlite described by A. LACROIX [11] from the Kakoulime massif, French Guinea. The symbol of the Sierra Leone rock under the C.I.P.W. classification is Kakoulimose.

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[10]. See J. H. L. VOGT—The Geology of the Platinum Metals; Econ. Geol. Vol. XXII, 1927, pp. 331 and 332.

[11]. Nouv. Arch. Mus. Hist. Nat., Paris, Vol. III, 1911, p. 114.

(6) *Later Intrusions.*

The rocks previously described are penetrated by minor intrusions (chiefly dykes) of the following types:—

(a) Gabbro pegmatite.
(b) Beerbachite.
(c) Dolerite.
(d) Micropegmatite.

Many of these rocks fill concentric and radial tension fissures formed by the sagging of the central portion of the intrusion, and some of them, e.g. the dolerites, show chilled margins indicating that they were intruded when the host rocks were cold. The later intrusions are less basic than the older gabbros, etc. and their order of intrusion—(1) gabbro pegmatite, (2) beerbachite, (3) dolerite, (4) micropegmatite—is one of decreasing basicity. According to Dixey [12] the micropegmatite (norite-aplite of Dixey) is older than the dolerite, but in sections seen by the writer this order appears to be reversed. On the foreshore north of York Point small veins of micropegmatite cut across a dyke of dolerite, and are clearly of younger age than the dolerite.

Table II.—Chemical Anlyses.

	316 %	393 %	315 %	A. %
SiO_2	77.38	50.58	46.35	48.79
Al_2O_3	11.83	16.88	11.98	11.96
Fe_2O_3	0.76	2.79	4.76	2.51
Fe O	0.30	6.02	12.13	12.10
Mg O	0.08	6.89	5.33	5.60
Ca O	0.60	13.26	10.13	10.15
Na_2O	2.40	2.45	2.42	2.40
K_2O	6.00	0.13	0.95	0.70
H_2O+	0.35	0.40	0.95	0.40
H_2O-	0.08	0.11	0.20	0.65
CO_2	nil.	0.05	0.77	0.41
TiO_2	0.18	0.62	3.45	4.17
ZrO_2	0.01	nil.	nil.	
P_2O_5	0.01	tr.	0.44	0.37
Cl	tr.	tr.	tr.	
S	0.01	0.01	0.02	
MnO	tr.	0.15	0.47	0.21
SrO	nil.	tr.	tr.	
BaO	0.04	tr.	0.05	
Li_2O	tr.	nil.	nil.	
V_2O_3	0.01	0.06	0.05	
Cr_2O_3	nil.	0.02	tr.	
Ni O	nil.	nil.	nil.	
Total	100.04	100.42	100.45	100.57
Gravity Specific	2.60	2.90	3.01	

12. Op cit. pp. 316 and 317.

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Fig. 5.

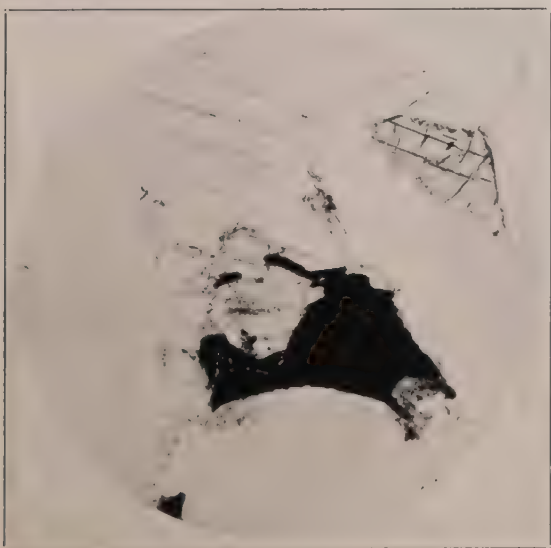

Fig. 6.

PLATE III.
Communication No. 43

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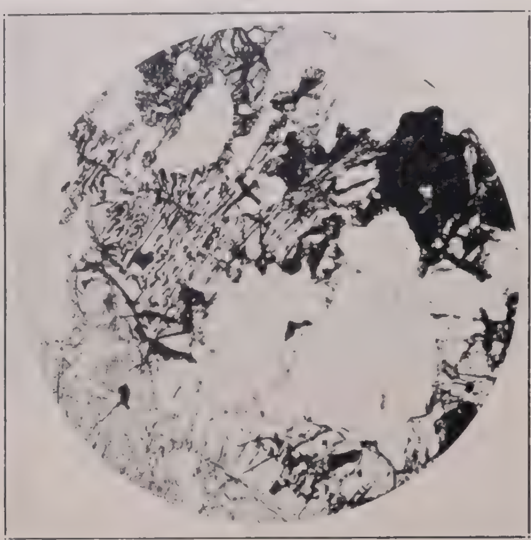

Fig. 7

Fig. 8.

PLATE IV.

Communication No. 43

NORMS.

		316 %	393 %	315 %
Quartz		39.0*	0.28	0.69
Orthoclase		35.45	0.78	5.62
Albite		20.29	20.71	20.45
Anorthite		2.99	34.82	19.11
Corundum		0.29	—	—
Diopside	$CaSiO_3$	—	12.80	10.89
	$MgSiO_3$	—	8.17	5.31
	$FeSiO_3$	—	3.80	5.39
Hypersthene	$MgSiO_3$	0.20	8.98	7.96
	$FeSiO_3$	—	4.19	8.08
Magnetite		0.43	4.05	6.90
Haematite		0.47	—	—
Ilmenite		0.33	1.17	6.55
Pyrite		0.02	0.02	0.04
Apatite		0.02	nil.	1.0
Calcite		—	0.11	1.75
Zircon		0.02	nil.	—
Water		0.43	0.51	1.15
		100.00	100.39	100.89
		Alaskose.	Auvergnose.	Camptonose.

316—Micropegmatite—Big Water near York Pass Forest Guard barracks.

393—Beerbachite—Near Lumley Road Station.

315—Dolerite—Big Water near York Pass Forest Guard barracks.

A— Basalt—Molmatindur, Eskifjord, Iceland (A. HOLMES, Min. Mag., 1918. Vol. 18, p. 192). The total 100.57% includes 0.15% of minor constituents.

(a) Gabbro-pegmatite:—In many places in the coarse grained gabbros there are irregular veins and patches, up to about 2 feet in width, of very coarse grained gabbro—pegmatite, containing individual crystals up to 4 or 5 inches in size. The pegmatites are dark coloured rocks composed largely of pyroxene (mainly bronzite) and plagioclase with some titanomagnetite and a little interstitial biotite and quartz. Small miarolitic cavities lined with quartz and containing a little chalcopyrite occur in these pegmatites near Toke, York and John Obey.

On the foreshore between Bura Town and Kent two small very coarse grained dykes penetrate the banded troctolite of the locality. The dykes are composed mainly of plagioclase with about equal amounts of diallage and titanomagnetite, and a little orthorhombic pyroxene. The titanomagnetite cements and veins the plagioclase and pyroxene. Irregular shaped leucocratic segregations composed of zoned plagioclase (albite to andesine), pale green diallage, quartz, microperthitic orthoclase, and titanomagnetite.

together with a little biotite, chalcopyrite and pyrrhotite, are present in the dykes.

(b) Beerbachite:—Rocks of this type are associated with anorthosite and troctolite near Hastings, Porcupine ridge, Mt. Aureol and Wilberforce, and small dykes of beerbachite have been found in numerous places.

The beerbachites are medium and dark grey fine and even grained granular rocks composed essentially of weakly zoned plagioclase (labradorite), orthorhombic and monoclinic pyroxene, and titanomagnetite (see Plate V, fig. 9). Orthorhombic pyroxene (hypersthene mainly) is usually in excess of the monoclinic pyroxene. In the specimen analysed (No. 393) the pyroxene is partly a very pale green monoclinic variety showing the multiple twinning characteristic of diallage, but relatively free from schillerisation and partly hypersthene. Olivine is exceptional and in the few sections in which it is present it appears to have been derived from the wall-rocks. A little deep red biotite, and a trace of quartz, occur in odd sections. The texture of the rocks is allotriomorphic and granular. Small porphyritic phenocrysts of plagioclase are present in certain specimens.

The average specific gravity of four samples of beerbachite is 3.02.

The Sierra Leone beerbachites closely resemble the rocks described as "granulitic gabbros" from Skye[13] and Loch Fuaran,[14] and also the fine grained granulitic phase of the Duluth Gabbro.[15] In Skye, and at Duluth, the coarse grained gabbros penetrate the "granulitic gabbros." In Sierra Leone this order is generally reversed.

(c) Dolerites:—These occur as dykes ranging in width from less than an inch up to several yards. The smaller dykes and the margins of many of the larger dykes are chilled black aphanitic rocks. The average specific gravity of three samples of dolerite is 3.01.

Hand specimens are medium grey to black in colour and fine to very fine grained. Small porphyritic phenocrysts of plagioclase occur in a few specimens, and one dyke near Dublin, Banana Islands, contains small vesicular cavities filled with quartz.

Thin sections generally consist of micro phenocrysts and laths of well zoned plagioclase having an average composition about Ab_1 An_1, abundant small grains of titaniferous augite, and a relatively large amount of finely divided granular titanomagnetite. Some enstatite, and a little biotite, green hornblende and apatite, are present in most sections and scanty chlorite, sericite, orthoclase and quartz in others. The texture is usually intergranular in the finer grained dolerites and ophitic in the coarser grained rocks.

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13. The Tertiary Igneous Rocks of Skye, Mem. Geol. Surv. 1904, p. 118.

14. The Tertiary and post-Tertiary geology of Mull. Mem. Geol. Surv. Scotland, 1924, p. 252.

15. M. L. Nebel—Econ. Geology, Vol. XIV, 1919, p. 379.

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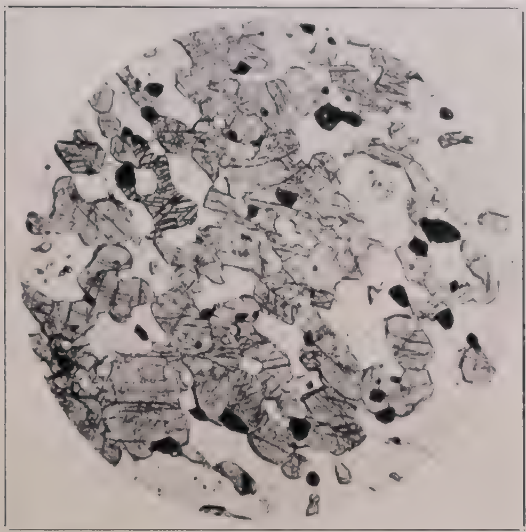

Fig. 9.

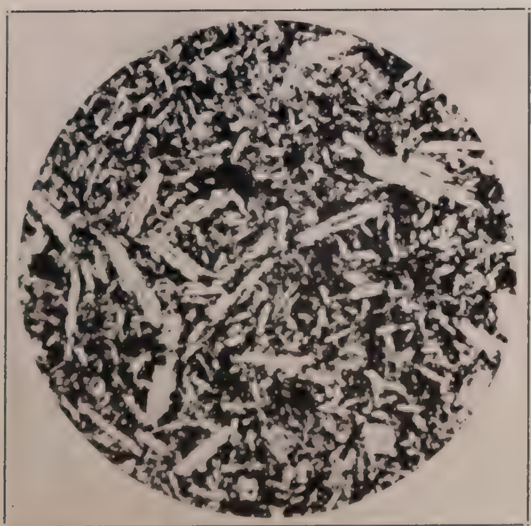

Fig. 10.

PLATE V.

Communication No. 43

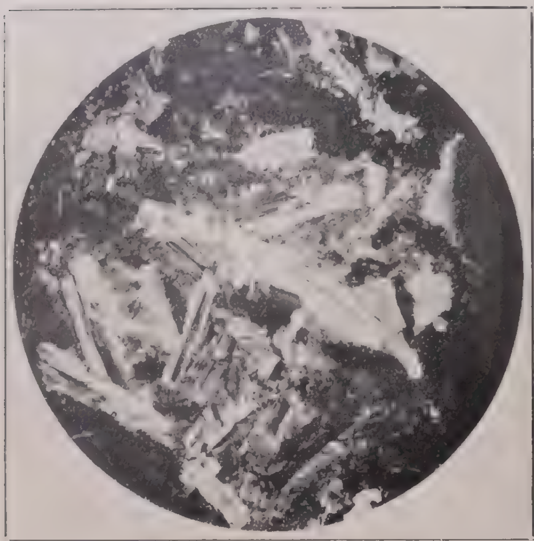

Fig. 11

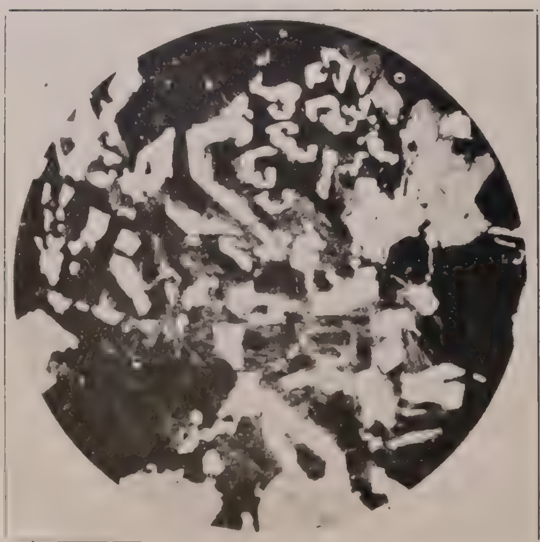

Fig. 12.

PLATE VI.

Communication No. 43

The specimen analysed (No. 315) is from a narrow dyke cutting anorthosite. The minerals in the section are zoned plagioclase, granular titaniferous augite, black iron oxides, and a little enstatite, biotite, and apatite. The chemical analysis of the rock is very similar to that of a plateau-basalt from Iceland (see Table II).

(d) Micropegmatite:—The youngest igneous rocks in the complex are light coloured ones of acidic composition. They occur as small dykes, "veins," and segregations, ranging from mere threads up to about 9 inches in width. Their volume is negligible compared with the other rocks of the intrusion.

Near York there are two sets of acid veins; one set trends parallel to the banding of the older gabbros, and the other set trends at right angles to the banding and dips near vertical.

The sample of micropegmatite analysed (No. 316) is from a small dyke, 3—6 inches wide, cutting anorthosite in the Big Water near York Pass Forest barracks. It is a pale pink to white coloured rock containing miarolitic cavities lined with crystals of quartz. The specific gravity of the rock is 2.60. The thin section of the specimen is composed of quartz, orthoclase, and microperthite, with a little albite and deep brown strongly pleochroic biotite, and scanty titanomagnetite, zircon and apatite. A graphic intergrowth of quartz and orthoclase forms a large part of the section. (see Plate VI, Fig. 12).

The analysis shows the extremely acid composition of the rock; the percentage of silica, 77.38, being unusually high.

In another specimen of micropegmatite from a "vein" traversing a dolerite dyke near York some colourless pyroxene (enstatite) which is partly changed to green hornblende and biotite, is present in addition to the above mentioned minerals.

According to Daly,[16] in the large basic sheets of the Bushveld, Sudbury, Purcell or Minnesota type, a micropegmatitic roof differentiate always overlies a gabbroid or diabasic phase carrying interstitial micropegmatite or schliers or "veins" of the same material. In Sierra Leone the micropegmatitic roof differentiate is absent. This may be due to the fact that in the Sierra Leone intrusion the differentiation did not advance as far as in the above mentioned sheets, but it is also possible that a micropegmatite cover to the intrusion existed at one time and has since been removed by erosion, together with a great thickness of the rocks forming the roof at the time of the intrusion.

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[16] Sills and Laccoliths illustrating Petrogenesis. C.R. de la XIII Session Internat. Geol. Congress, 1913.

IV. Economic Minerals.

(1) *Titaniferous Iron Ores.*

Bands and lenticular "veins" of massive ilmenite and titanomagnetite, and "schlieren" and bands of magnetite—olivine rock, magnetite-rich troctolite, and magnetite-gabbro, occur in several places in the rocks of the complex. For the most part the ore bodies are concordant with the primary banding of the intrusion, and they are generally associated with anorthosite. On one horizon in the banded troctolites of the lower part of the intrusion concordant bands of massive ilmenite and titanomagnetite—at least 15 feet and 7 feet thick, respectively at Mt. Aureol and near Hastings—have been traced from Hastings through Porcupine ridge to Mt. Aureol (Freetown) and Aberdeen. Anorthosite and anorthositic gabbros are often associated with the titaniferous iron ore. Near Hastings the ore is chiefly ilmenite. Some felspar occurs in the ilmenite near the walls. At Mt. Aureol and Porcupine ridge the material is mainly titanomagnetite. The presence of 4.36% Cr_2O_3 in the analysis of the ore is interesting, as no deposits of chromite have been found in the rocks of the complex and only rare grains of chromite have been seen in thin sections of the rocks.

Table III.—Chemical Analyses.

A	B	C	D		
%	%	%	%		
Fe_2O_3	25.06	76.92[17]	—	Platinum.	87.0
Fe O	28.02	—	—	Osmiridium.	1.3
Ti O_2	42.34	15.70	46.81	Palladium	2.0
V_2O_5	0.38	0.69	—	Iron.	9.9
Cr_2O_3	nil.	4.36	0.29		

A—Ilmenite from deposit at Forest Guard hut near Hastings.

B—Titaniferous iron ore, Mt. Aureol, Freetown.

C—Platinum bearing black sand concentrate from the Big Water near York Pass. Analyst:- L. S: Theobald.

D—Alluvial platinum from the Big Water near York Pass Forest Guard Barracks. Analyses A, B and D were made by the Imperial Institute, London.

In a few of the rocks rich in titaniferous iron ores e.g. magnetite-olivine rock from Mt. Aureol and magnetite troctolite from Aberdeen, the iron ores appear to be contemporaneous with the associated silicates, but in the majority of cases they have separated after the silicates. Iron ores are more abundant in the later dyke rocks, particularly in the dolerite, than in the earlier banded gabbros.

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[17]. In this analysis all the iron is calculated as Fe_2O_3.

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Fig. 13.

PLATE VII.

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(2) *Platinum.*

Deposits of alluvial platinum were discovered in the York district in 1926. A good deal of the platinum is of coarse grain; two small nuggets weighing 7.4 grams and 1.7 grams respectively were found by the writer in the Big Water near York Pass. The platinum is associated with ilmenite and titanomagnetite and scanty chromite. An analysis of the crude platinum recovered by panning is given in Table III.

The source of the platinum has not yet been found, but no systematic examination of the rocks for platinum has been made.

V. Genetic Summary.

The Sierra Leone intrusion—the exposed area of which is about 170 square miles—is portion of a large basin-shaped sheet of the quartz-gabbro kindred. The central and western part of the sheet is cut off on the seaward side. The floor of the intrusion is not visible and the roof rocks have been removed by erosion.

Several other intrusions of a similar type, and swarms of related dolerite dykes, occur in a more or less straight line, close to, and parallel to, the coast for a length of more than 150 miles, between French Guinea and Liberia. These linear intrusions indicate that the region was in a state of tension at the time of their injection.

The various rocks have a stratiform arrangement, and they show a well defined primary banding (fluxion structure). The rocks in the lower part of the exposed portion of the intrusion are mainly olivine-rich troctolites and they are a little more basic than the rocks near the top of the sheet. The rocks are not arranged in simple gravitative differentiation layers.

The oldest, and by far the most abundant, rocks in the intrusion are well banded medium grained troctolites, and ordinary, and olivine-bearing gabbros and norites.

While still hot these rocks were invaded by masses—of relatively small size compared with the banded rocks—of coarse grained gabbro and norite (including olivine-bearing types), with some peridote, and a little dunite and gabbro-pegmatite. These rocks are either free from banding, or are poorly banded. The large sheet-like body of coarse grained anorthosite near York Pass appears to be intrusive into the banded rocks and may have been formed at this stage. Most of the coarse grained intrusions occur as concordant lenticular bodies, and they appear to be less prominent in the lower part of the sheet than they are higher up in it. Some of them may represent interstitial rest-magma pressed out by earth movements at stages during the crystallisation of the magma.

Concentric and radial tension fissures were developed by the sagging of the central portion of the cooled intrusion and many of these fissures were filled with small dykes of beerbachite, dolerite and micropegmatite. The last named rock occurs in insignificant amounts and represents the residual magma squeezed out when almost the whole of the intrusion had solidified.

Olivine gabbro (including troctolite and olivine norite) is the most abundant rock in the intrusion. Ordinary gabbro and norite are next in order of importance. These are followed by moderate amounts of anorthosite and anorthositic gabbro, and small volumes of peridotite, beerbachite and other rocks. Troctolite is probably the most common individual rock type. The peridotites are unusually rich in FeO, relative to MgO, and they are intermediate in composition between the ordinary peridotites and the unique hortonolite dunites of the Bushveld.

Massive titaniferous iron ores are fairly common. They form persistent bands on one horizon in the troctolites in the lower part of the intrusion. Chromite is apparently very rare. Deposits of alluvial platinum occur near York. Platinum has not been found in economic quantities in the rocks, but they have not been carefully examined.

The magma was a dry one and was apparently rich in iron. All the rocks are remarkably fresh (this is illustrated by the very low percentages of H_2O and CO_2 in the analysis) and, apart from strain shadows, and slight twisting of the twin lamellae, in some of the plagioclase, they show very little evidence of pressure metamorphism.

Plagioclase is the most abundant mineral in the rocks. The bulk of it has a composition near $Ab_1 An_2$. The plagioclase in the dolerites has an average composition of $Ab_1 An_1$, and in the micropegmatites it is nearly pure albite. Pyroxene and an iron rich olivine, containing between 30% and 40% $Fe_2 SiO_2$, occur in about equal amounts. The olivine in the peridotite and dunite is unusually rich in FeO for rocks of this type. Monoclinic pyroxene (usually diallage) is in excess of orthorhombic pyroxene which is chiefly hypersthene.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Olivine gabbro (No. 285) from No. 2 river near the Forest Guard hut, showing reaction rims of hypersthene and diallage around olivine. X 17 O.L.

Fig. 2. Olivine gabbro (No. 290) from No. 2 river to Toke by bush track at 2.2 miles, showing plagioclase, diallage and olivine, X 13 O.L.

PLATE II.

Fig. 3. Olivine norite (No. 357) from near Russell, showing plagioclase, olivine, hypersthene, titanomagnetite and biotite. The titanomagnetite penetrates the olivine and hypersthene. X 16 O.L.

Fig. 4. Troctolite (No. 259) from Sugarloaf gap on track between Regent and Sussex. X 20 Crossed nicols.

PLATE III.

Fig. 5. Anorthosite (No. 304) from the Big Water near York Pass Forest barracks. Note the cracks and lines of inclusions in the plagioclase. X 13 Crossed nicols.

Fig. 6. Anorthosite (No. 392) near Lumley road railway station, showing reaction rims of biotite and cloudy colourless zoisite? around titanomagnetite. X 25 O.L.

PLATE IV.

Fig. 7. No. 340 Bura Town to Kent, coast section at I. Im., showing intergrowth of magnetite and hypersthene. X 21 O.L.

Fig. 8. Hypersthene peridotite (No. 236) from Baw Baw to No. 2 at ½ m., showing cracked olivine with lines of inclusions, and schillerised hypersthene. X 14 O.L.

PLATE V.

Fig. 9. Beerbachite (No. 393) from near Lumley road station, showing hypersthene, augite, plagioclase and titanomagnetite. X 25 O.L.

Fig. 10. Chilled dolerite (No. 315) from Big Water near York Pass barracks. The rock contains abundant finely granular titanomagnetite. X 28 O.L.

PLATE VI.

Fig. 11. Dolerite (No. 234) from 0.4 m. north of York Point. Note the zoning in the plagioclase. X 18 Crossed nicols.

Fig. 12. Micropegmatite (No. 316) from Big Water near York Pass barracks. X 13 Crossed nicols.

All the photomicrographs were made by MR. G. S. SWEETING, F.G.S.

PLATE VII.

Fig. 13. Weathered surface of banded norite.

44. ASSIMILATIONS ERSCHEINUNGEN IN DEM HARGHITAZUGE DER OSTKARPATEN

VON

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Chefgeologe.

In letzter Zeit habe ich im Auftrage des Rumänischen Geologischen Institutes das Studium dieses wenig bekannten, jung vulkanischen Gebirgszuges vorgenommen. Die Resultate meines Studiums berühren mehrere der für Discussions Object gemachten Fragen des Congresses, deshalb gedenke ich die Aufmerksamkeit auf sie zu lenken.

Der Harghitazug—hingerechnet auch das Görgény (Gurghiu) und Kelemen (Caliman) Gebirge—erhebt sich bis über 2100 m. hoch dort, wo die Karpaten im Osten, im Angesichte der alten caledonischen und variscischen Krustenteile (Russische Tafel) auf das Werfen ihrer schönsten und stärksten Bogen gezwungen waren.—Mit seinem NW—SO Verlauf durchbricht er diesen Bogen. Nach dem Durchbruche auf einem Südende spaltet er sich in drei Zweige. In die Richtung der westlichen Zweige folgt die Dâmbovita tektonische Linie, ferner die bulgarische Svitow Basaltlinie und das Gebiet des bulgarisch-griechischen Erdbeben vom April 1928. Der Hauptmittelzweig streicht direkt der Picineaga tektonischen Linie von Dodrudsa, während der östliche Büdöszweig sich in die bedeutendste Erdbebenlinie von Rumänien, der Focsani Galati-Tulcea tektonischen Linie verlängert. Auf diese Weise kommt der *Harghitazug in Verbindung mit dem Pontus und Ägäischen Einbrüchen, welche sich anderseits durch die Sues-Rotesmeer Verzweigung den ostafrikanischen Grabenbrüchen anschliessen.*

Gegen Norden ist die teils unterirdische Verbindung des Harghita mit der erzführenden Rodna,—Kapnik und Gutin-Vihorlat Andesit-Kette evident. Diese tektonische Richtung schneidet gegen Norden auch den Karpatenbogen in seiner niedrigsten Stelle, im Duklapasse durch. Die meridian gerichtete Tokaj-Eperjeser Vulkankette, in deren Verlängerung die 70°C Wasser liefernde Hajduszoboszloer Bohrung und Eruptionslinie von Belgrad liegt, streicht auch in dieser Richtung. Prof. Dr. W. TEISSEYRE verlängert diese NW Richtung, in welcher auch Island liegt, in seiner "Metoda kryptotektonika" (Kosmos 1926) bis Skania.

Der Harghitazug durchbricht diesen uralten schwachen Teil der Erdkruste dort wo der successive sehr verkleinerte siebenbürgische Tertiärbecken, am Ende des Neogens, am tiefsten gelegen war. Bei diesem Durchbruche haben die Explosionen, deren Urheber hauptsächlich das Wasser der nassen jungen Sedimente war, gewaltig mitgeholfen. Nördlich und südlich von dem Harghita, in der älteren, trockenen, mehr ausragenden Kruste, ist das Magma grösstenteils stecken geblieben, nur die fortdauernden Exhalationen und die enthüllten Eruptiva geben Kund von seiner Rolle.

Der Harghitazug ist hauptsächlich aus *Amphibol—und Pyroxenandesit* aufgebaut. Diese gehen aber vielfach teils in olivinführende *Basaltandesite, bis Basalte*, teils in *Quarz und biotitführende Andesite bis Dazite über*. Das Erscheinen der saueren Eruptiva auf den Enden, den extremen Teilen des Zuges, wo die Berührung mit der alten, saueren, auch als Einschlüsse sich verratenden Kruste am innigsten war; die Rólle der Elemente der wasserführenden Mineralien (Amphibol, Biotit); der Aufbau der Feldspate, deren oft recourrente, oder inverse Zonen in demselben Kristall oft von Bytownit bis Oligoklasandesin reichen; wie auch die Mächtigkeit der Breccienhüllen; ferner die Folge der zweimal mit dem saueren Teil begonnenen und mit dem basischen endigenden Eruptivreihe: alle diese Eigenschaften zeigen darauf hin, dass *bei der Bildung dieser Gesteine die Assimilation eine grosse Rolle gespielt hat*.

Diese Eruptionen der Harghita knüpfen sich direckt den vorangehenden Dazittuffausbrüchen des westlich gelegenen Beckens an.

In der sarmatischen Zeit erscheinen die Amphibolandesit Explosionsvulkanprodukte im Norden an der Maros (Mures), welche bald mit Basaltandesiten verdeckt wurden. Letztere gehen gegen Norden successive in Pyroxenanadesite über, gegen Süden aber wurden sie von einer zweiten, mächtigeren Reihe von Amphibol-andesitbreccien und später-Laven bedeckt, auf welche dann die Haupt-Pyroxenandesitergüsse folgten. Zuletzt haben sich die geschwächten Tätigkeiten auf die beiden Seiten zurückgezogen, wo sie neben Pyroxenandesit hie und da auch wenig Basaltandesite erzeugten.

Die Ausbrüche haben sich von Norden successiv gegen Süden verbreitet, wo sie noch gegenüber den imposanten Kalderenruinen des Norden (Mezöhavas, Kelemen) auch ihre frische Kraterform (Szt. Anna) bewahrt haben. Hier dauerte ihre Tätigkeit bis ins Pleistozen hinein.

Ausser den gewöhnlichen Ejectivas und Laven kommen in dem Harghitazuge vielfach auch *aufgequollene, propfenartige Breccien* vor, welche Erscheinungsform, in Verbindung mit vielen anderen Eigenschaften, eine Ähnlichkeit mit den Javavulkanen zeigt.

Mit den letzten Pyroxenandesiteruptionen, hauptsächlich in dem zentralen Teile des Zuges, sind auch minder bedeutende *Gold-Silber-Quecksilber—etc.* führende Sulfiderze, Schwefel auf die Oberfläche gekommen.

Die höchste Bedeutung erlangen aber im Harghitazuge die mit dem Rückgange des Vulkanismus erschienenen *Kohlensäure Exhalationen,* Säuerlinge und überhapt Mineralquellen, die diese Jungvulkane, auch ausser ihrer Kette in einem breiten Gürtel umgeben. Wo die Säuerlinge aufhören, erscheinen im einem weiteren Gürtel die *Methangase* und in der Südrichtung des Zuges, etwas gegen das Vorland gerückt, die reichsten *Petroleumfelder* Rumäniens (Cämpina etc.), gegen Norden aber folgen die von Polen (Boryslav, —Tustanovice).

Ich will noch die Aufmercksamkeit auf den wichtigen Umstand lenken, dass der Harghitazug in Osten das *Nephelinsyenitgebiet von Ditro* (*Ditrau*) durchbricht, welches im Sinne der Daly-schen Hypothese, als Assimilationsproduckt des Kalksteins zu betrachten ist. Dieser Nephelinsyenit schliesst aber—wie Mauritcz Miklós, Vendel und Harwood gezeigt haben,— auch pazifische Glieder (Camptonit, Umptekit) ein, welche ihrer chemischen Zusammensetzung nach dem Basaltandesite der Harghita nahe stehen. *Der innige Zusammenhang der sogennanten pacifischen und atlantischen Sippe ist hier also evident,* Von diesem Nephelinsyenitgebiet zieht sich ein noch wenig bekannter *Alkaligneiss-zug* gegen Süden, wo in dem Persaner Gebirge auch Sanidinporphyr-gänge bekannt sind.—Westlich von dem Harghita, in den Konglomeraten des neogen Beckens von Siebenbürgen, fand ich auf einen viel gröseren Gebiet, bis Nahe Zsibo (Zibo) rote Alkaligranite, die ich als Bruchstücke alter, ortsständiger Gebirge betrachte.—Die tusnader Biotitandesite enthalten auch Titanit und den Alkaligesteinen schliesen sich im Osten *Alkalimineralquellen* an.—Alles dieses sind Zeichen genetischer Zusammenhänge der sehr verschiedenen eruptiven Gebilde.

45. ALTER UND VERBAND DER JUNGEN GRANITE IN SÜDWEST AFRIKA

VON

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ABSTRACT.

Granite, dis jünger sind, als die Tafelbergformation des Herorolandes und Kaokofeldes (wahrscheinlich Karroo), habe ich 1911 im Erongogebirge festgestellt und im Brandberg und Spitzkopje vermutet. Inzwischen konnte ich auch für den Brandberg des jugendliche Alter beweisen. Die umgebenden Sedimente und Eruptivdecken treten fast ungestört an den zentralen Granit heran und biegen erst wenige 100 m. von dem Contakt gegen diesen *hinab* (mit 30-60°.) Der zentrale Granit ist ein Hornblendegestein. Mit dem Nebengestein ist er durch eine mächtige Contakt und Intrusionzone (z.T. mit feinen Durchtränkungen) verbunden. Auf einem (oder mehreren?) Gipfeln des Gebirgs liegen Reste der gleichen Melaphyrdecken und Eruptivbreccien horizontal. Wie am Erongo ist offenbar auch im Brandberg der fehlende Teil der Schichttafel in den aufsteigenden Granit eingebrochen. Eine Granittektonik fehlt (im Gegensatz zu dem sonst ähnlichen Yosemitepluton in Californien). Der Brandberg und der Erongogranit scheinen in ganz geringer Tiefe unter der Oberfläche erstarrt zu sein.

46. ÜBER DEN VESZELYIT VON VASKÖ (MORAVICZA) UND SEINE STELLUNG ZUM ARAKAWAIT UND KIPUSHIT

VON

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Budapest.

Eine neue, mit gutem und reichlichem Material ausgeführte krystallographische und chemische Untersuchung des Veszelyites von Vaskö ergab das Axenverhältnis $a:b:c = 0.729:1:0.954$,

$\beta = 76°37'$,

und mit sehr guter Übereinstimmung die chemische Formel

$(Cu, Zn)_3' (PO_4)_2' 3(Cu, Zn) (OH)_2' 4 H_2O$

mit dem ungefähren Verhältnisse

$CuO: ZnO = 3:2$.

Das untersuchte Mineral enthält also keine Arsensäure, gegenüber den Angaben von Schrauf, der es zuerst beschrieb.[1]

Mit der oben angegebenen Formel ist diejenige des Arakawaites[2] nach Buttgenbach[3] identisch. Die chemische Zusammensetzung des zu letzt genannten Minerales unterscheidet sich von derjenigen des Veszelyites von Vaskö bloss durch das Verhältnis

$CuO:ZnO =$ ungefähr $5:3$

Vom Kipushit[4], dessen Axenverhältnis für die II. Aufstellung von Schrauf[5], die auch Spencer-Mennel für den Veszelyit von Broken-Hill (Nord Rhodesien[6]) Wakabayashi und Komada für den Arakawait[7] angenommen hat und die auch ich gebrauchte

$a:b:c = 0.740:1:0.906$,

$\beta = 76°57'$ ist,

und dessen chemische Formel:—

$(Cu, Zn)_3.(PO_4)_2.3(Cu, Zn).(OH)_2.3 H_2O$ geschrieben werden kann, unterscheidet sich der Veszelyit von Vaskö in der chemischen Zusammensetzung bloss im Wassergehalte und im Verhältnis

$CuO:ZnO = 4:5$.

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(1) Anz. Akad. Wien, 135-137, (1874); Zs. f. Kryst., 4, 31-33, (1879).
(2) Wakabayashi und Komada, Journ. Geol. Soc. Tokyo, 28, 191-211; Auszug im Min. Magazine, Abstracts, 1, 250-251 (1920-1922).
(3) Acad. R. de Belgique, Bull. de la Classe des Sciences, 911 (1926).
(4) Buttgenbach, loc. cit., 905-913.
(5) Zs. f. Kryst., loc. cit.
(6) Min. Magazine, 19, 69-72 (1922).
(7) Loc. cit.

47. NOTES ON THE BERYL OCCURRENCES IN NAMAQUALAND.

BY

P. KOVALOFF.

The exceptional properties of metallic beryllium, which open a wide field of application of this metal for industrial purposes and especially in the construction of aeroplanes, etc., have lately been attracting widespread interest and attention in scientific and industrial circles.

The extraction of this metal from Beryl—which forms its chief ore—has not yet been effected on a commercial scale, chiefly because the supply of ore has, up to now, been very restricted and uncertain. So far as the writer is aware, there has never been any serious attempt to mine common Beryl solely for its beryllium content, and the very limited consignments of the ore which have reached the markets have been derived—as a by-product in the mining of some other mineral, such as gem quality beryl, emerald, feldspar, etc.

It is only some three months ago (May, 1929) that the deposits of Beryl in the Namaqualand pegmatites first attracted interest in South African Mining Circles, as a possible source of beryllium in commercial quantities and which would justify the mining of Beryl as a principal ore.

Early in July, the writer paid a short visit to Namaqualand where the Beryl occurrences are now being systematically and energetically prospected, chiefly with a view to investigating the economic possibilities of the deposits, and though the time at his disposal was so limited, that he was unable to do justice to the very interesting geological features of the occurrences, he still considers it appropriate to place on record—even at the present stage—some of his observations on the deposits, which, as he hopes to show, can be worked solely for the production of Beryl as a principal ore.

The occurrences of Beryl crystals in the pegmatites of Namaqualand in and around the locality known as Jackals Water, has been known for some years, and as far as I could ascertain was recorded first by DR. A. W. ROGERS in his paper "Notes on the Occurrence of Radioactive Minerals in South Africa," read before the Geological Society of South Africa in April,

1915.(¹) At the time this paper was read, the demand for common beryl was very restricted, or did not exist at all, and no industrial importance was attached to the discovery. It is only during the past two or three years, when satisfactory methods of obtaining beryllium in metallic form on a large scale have been evolved; the properties of the alloys of beryllium with other metals have been ascertained, and the constantly increasing demand for the raw material has come into being, that private enterprise was induced to support an effort to locate a promising source for the supply of this growing need. Interest in the Namaqualand beryl occurrences was thus aroused and energetic work organised.

The locality where the presence of beryl in pegmatites has been established, represents a part of arid country with a dearth of water and vegetation, and lies within a belt of 30 to 40 miles in width, along the Southern bank of the Orange River. The name "Jackals Water" (which is the locality where the first discovery of beryl was made)—is derived from one of the rare water-holes which constitute the only supply of brackish water for the modest needs of the small local human and animal population for miles around.

The Areas on which prospecting work, organised by the recently formed Company, "Beryllium, Ltd.", is now in progress, are situate from 20 to 35 miles to the North East of Steinkopf Village, which has a railway station on a privately owned line—the property of the Cape Copper Company—from the Concordia Copper Mine, to Port Nolloth on the Atlantic Ocean. The distance from Steinkopf to Port Nolloth—which is the natural outlet for the locality in question—is sixty miles.

The Geological structure of the locality has been described by Dr. A. W. Rogers. (²) Generally speaking the area, where beryl occurrences have been discovered, is composed of gneissose rocks, representing the result of at least 2—and probably more—subsequent intrusions of acid Magma. These rocks are cut by numerous pegmatite veins. There is, as yet, no certainty as to which acid intrusion gave rise to these pegmatite veins. The field evidence shows however, (as was pointed out by Dr. Rogers) that these veins are of a later date than the surrounding rocks.

Owing to the marked contrast of the white colour of the pegmatites to the monotonous greyish appearance of the gneissose rocks, the former represents a conspicuous feature of the country. (Fig. 1.)

In traversing the country one observes many hundreds or some thousands of these pegmatite veins, which often intersect each other in a complicated network. In general, however, the trend of these veins, from

(¹) Trans. Geol. Society. S.A. Vol. XVIII, 1915, pp. 5-10.

(²) Op. cit. and also: "Report on a Portion of Namaqualand," Annual Report S.A. Geological Survey 1912, p. 127 and following.

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Fig. 1. Outcrops of pegmatite veins on a hill composed of sheared gneisses, Jackals Water, Namaqualand.

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Fig. 2. Crystal of beryl at Jackals Water, Namaqualand.

South of South-east to the North of North-west (Magnetic), is noticeable in the locality traversed.

The structure of the pegmatites is varied. In most cases the pegmatites display a pronounced graphic structure closer to the walls of the veins, while towards the middle, coarse grained pegmatites of granophyric structure are developed, with large crystals of microcline and accumulations of white and rose quartz. Miarolitic cavities, characteristic of this latter structure of pegmatites, are absent, and probably the accumulations of quartz just mentioned, may be regarded as the result of the filling up of these cavities by residual quartz after the crystallisation of the eutectic. Apart from the main constituents of the pegmatites in this locality (microcline and quartz) the following is the list of minerals occurring in these veins.

(1) *Beryl.* Sometimes found in large crystals up to five feet in length, and fourteen inches in diameter. (Fig. 2.)

This mineral occurs: (a) as scattered crystals in the usual form of 6 sided prisms, sometimes with a vertical striation in the prismatic zone, and (b) in aggregates of crystals, sometimes of considerable size. The largest accumulation disclosed up to the present in the course of prospecting work contained 16½ tons of beryl. The crystals are of greenish, and often of bluish (aquamarine) colour, but transparent crystals of gem quality have not yet been found.

The largest crystals and accumulations of crystals are generally associated with coarse grained pegmatites of the interior parts of the veins.

(2) *Minerals of the Columbite-Tantalite Group*, occurring in accumulations up to 70-80 lbs. in weight. The following are the results of analysis of 2 specimens of these minerals from Jackals Water, made by Dr. Moir, and given by Dr. A. W. Rogers in the paper referred to above:—

Columbic anhydride	32.8%	—	76.4%
Tantalic anhydride	2.8%	—	48.0%
Ferrous Oxide	9.1%	—	9.3%
Manganous Oxide	9.2%	—	9.7%

The specific gravity was found to range from 5.23 to 6.40.

(3) *Muscovite*, occurring at times in books of appreciable size representing a certain market value.

(4) *Pale Green Mica,* occurring sporadically.

(5) *Lepidolite,* forming irregular accumulations in veins.

(6) *Black Tourmaline,* sparsely represented.

The minerals just enumerated were observed together in one and the same pegmatite vein, opened up in a stretch of about 300 feet, in the course of prospecting work.

In addition to the above the following minerals are mentioned by Dr. A. W. Rogers as occurring in the pegmatites of this locality:—

(7) *Spodumene.*

(8) *Albite.*

(9) *Garnet.*(³)

The vein opened up during the prospecting work is characterised by a graphic structure of the pegmatites closer to the walls, and by coarse grained towards the centre, which suggests earlier epigmagmatic phases of the pegmatitic process. On the other hand the presence of Tourmaline, Albite, Green Mica, and Lithiumminerals goes to show that the process had not yet reached a finality during the later pneumatolitic stages, and that a considerable change in temperature had therefore taken place before the formation of the veins in this locality was accomplished.

From an economic point of view, so far as beryl is concerned, two points are of importance: (1) the quantity of the mineral available in the locality and (2) its payability. Regarding the first question, it must be pointed out that no systematic prospecting of the vast area over which Beryl occurrences are scattered has been done up to the present, and yet during the few weeks since work was commenced some dozen of beryl-bearing pegmatite veins have been discovered, and even during the few days of the writer's presence on the spot, new discoveries were made almost daily in different spots—mostly quite accidentally—during the course of pegging. This, in the opinion of the writer, at any rate shows, that the presence of Beryl is a general feature of the pegmatites of the locality, and that the parent magma, which gave rise to these veins was very rich in the volatile compounds of beryllium. The general impression of the writer is, that the total quantity of Beryl which the pegmatites developed in this locality contain, must be considerable—rather in the order of hundreds of thousands than thousands of tons.

As to the payability, the probable market price of the final product (beryllium metal) must be first considered. There is no doubt that the present price of beryllium (up to £10 per kilo) is abnormally high and it will in all probability drop considerably (say to about £4 per kilo) before a wide market for this metal for industrial uses can be obtained.

If we take this latter price as a basis and assume (1) 10% of Be O content in the Beryl ore mined, (2) cost of mining (which can be easily

(³) Since this paper was read, specimens of the following minerals found in the pegmatites of this locality, were sent to the writer: Metallic Bismuth, Corundum.

done by quarrying) 3s. per ton of mining material, (3) cost of extraction at £2 per kilo of beryllium and (4) percentage of extraction 60%,—a simple calculation will show that the limit of payability will be the content of beryl in the whole mass of pegmatite—6 kilos to the ton or approximately ½ per cent.

The actual results so far obtained in the course of prospecting work cannot, of course, be taken as a basis for a final conclusion concerning the beryl content of all the pegmatites in the locality, but they give at least a general idea how far the results obtained up to now exceed the limit of payability given above.

In the course of the prospecting done up to the present, (trenching across the whole thickness of one pegmatite vein) altogether approximately 400 tons of pegmatite was taken out, and from this quantity 20 tons of Beryl of an average assay value of 10.35% Be O was sorted out, which corresponds to 5% of beryl content over the whole width of the pegmatite vein. As the accumulations of beryl are, as previously mentioned, chiefly associated with those parts of the veins where the coarse grained structure is particularly developed, selective mining will enable the maintenance of a higher grade of beryl content in the pegmatites mined than would be the case if the whole body of the pegmatite were mined.

This margin between the actual results, and the limit of payability (even making due allowance to averse chance), hardly leaves a doubt that the exploitation of the pegmatite of Namaqualand for beryl as a principal ore, can be profitably undertaken and that in this locality South Africa has occurrences which possess potentialities of an important source of supply of raw material for beryllium extraction.

48. CONTRIBUTION A L'ÉTUDE DES GÎTES DE PLOMB DE LA TUNISIE SEPTENTRIONALE.

PAR

L. JOLEAUD.

Les gîtes métallifères de la Tunisie, plus spécialement ceux de plomb et de zinc, sont considérés généralement comme liés à des affleurements de Trias en situation anormale: les eaux hydrothermales, qui leur ont donné naissance, auraient cheminé par des fractures en relation avec des venues triasiques et se seraient épanchées per descensum dans des réseaux de cassures secondaires greffées sur les dislocations principales. Cette conception de la genèse des minerais du territoire de la Régence a été déduite de l'allure de diverses masses de plomb et de zinc, consistant localement en un gîte de contact entre le Trias et un terrain quelconque, avec expansions latérales sous forme de gisements inclus dans des cassures ramifiées à partir d'une grande faille.

Je pense qu'une telle interprétation ne doit pas être étendue à tous les gîtes de plomb de la Tunisie septentrionale. Plusieurs de ceux que j'ai étudiés en détail, djebel Touireuf, djebel Melaliess, djebel Tabouna, ne se lient génétiquement pas au Trias.

Au djebel Touireuf, par exemple, nous voyons se développer, loin de tout affleurement triasique, un réseau de fractures dans les calcaires du Crétacé supérieur et de l'Eocène inférieur, fractures qui tendent à se grouper en profondeur, en même temps que se manifestent des indications se référant à la substitution de la galène au carbonate. Latéralement, en surface, ce gîte filonien passe, au contraire à un gîte de contact entre les calcaires éocènes et les grès miocènes; se dernier gîte se retrouve dans de petits coteaux de la plaine de Bir el Abied, où, à partie terminale, se présente une sorte de chapeau de fer.

Au djebel Melaliss, des filons de plomb carbonaté recoupent les masses calcaires du Sénonien. Après un coincement dans les marnes du Crétacé moyen, le minerai reparaît dans les calcaires de la base du Cénomanien, qui forment une série renversée avec les formations précédentes: là encore se

manifeste, vers le haut du gîte, une tendance à l'individualisation d'un chapeau de fer.

Au djebel Tabouna, s'observent de nombreuses fractures minéralisées par du carbonate de plomb, auquel se substitue de plus en plus, vers la profondeur, de la galène. Au contraire, la calamine reste localisée au voisinage de la surface, ici comme dans d'autres gîtes tunisiens.

Pour ces trois gisements, la prospection montre qu'il ne saurait s'agir contrairement à ce qui a été dit, d'une formation minérale per descensum d'origine triasique, même accompagnée latéralement de remises en mouvement secondaires, en relation avec la perméabilité aux agents minéralisateurs de certains calcaires. En fait nous sommes ici en présence de gîtes de fractures, gîtes dont la formation est postérieure à celle des grès miocènes du djebel Touireuf.

49. THE STRUCTURE OF KAMBOVE-MINE.

BY

H. J. SCHUILING, M.E.
Geologist of "L'Union Minière du Haut Katanga."

INTRODUCTION.

Before passing to the description of the structure of the KAMBOVE MINE, I will first give a short description of the stratigraphy of the Upper-Katanga.

We have here a succession of sediments, accumulated in a vast basin in the ancient platform.

The age of these sediments is unknown, fossils have never been found.

In the centre of the basin they consist of a succession of lacustrine, in part marine, possibly to some extent of glacial beds. The thickness of this system, which is called by VAN DOORNINCK "THE SYSTEM OF THE KATANGA" in his book: "DE LUFILISCHE PLOOING," is certainly not less than 15,000 feet and no unconformity in it has been observed so far.

The lowest known series of the system in the environs of KAMBOVE (which is at the same time the lowest known series of the whole basin) is the so-called: "MINE SERIES" ("SERIE DES MINES"), a complex of dolomites and dolomitic shales, about a thousand feet thick. This series, being economically the most important, will be described in detail further on.

Above there is found the N'GUYA or M'WASHIA series, including in the lower section silicified dolomites, with black chert bands, showing oolitic structure and banded shales towards the top. The latter include one or more layers of graphitic shales, which are quite white at the surface as a result of oxydation. Thickness about 1,000 feet.

Then follows the Katanga big conglomerate, possibly of fluvio-glacial origin, with interstratified shaly bands. The percentage of pebbles is low; all sizes up to one foot diameter occur: at least 95% of the pebbles are quartzites. Near Kambove the conglomerate is very thick, fully 2,000 feet. The transition from the underlying banded shales to the conglomerate, as well as that from the conglomerate to the overlying shales, which are also often finely banded over a small distance, is imperceptible.

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No. 1. "Roches Siliceuses Feuilletees."

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No. 2 "Roches Siliceuses Cellulaires."

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On top of this lies a thick complex of more or less calcareous shales, which include not far (± 400 feet) above the Conglomerate a lenticular pure limestone, the so-called Kakontwe limestone, which is being worked in a quarry of that name.

At about 3,500 feet above the first conglomerate exist the "LITTLE CONGLOMERATE," much thinner, varying from 30 to 150 feet, having a shaly matrix with small mostly quartzite pebbles.

From this upwards we have at least 6,000 feet of monotonous calcareous shales, without well recognisable horizons.

The whole succession above the big conglomerate is called the "KUNDELUNGU" or "KATETE SERIES."

The Katanga system is folded along axes trending E-S-E—W-N-W to the East and almost E-W to the West of Kambove.

In the Kambove region this folding is intense and often of isoclinal character, with the axes overturned and accompanied by faulting.

The axes can be overturned to the N-E as well as to the S-W. Longitudinal faulting along the axes of the anticlines is common (strike faults); the same exists probably along the axes of the synclines.

The reason that they are better known in the anticlines are:

1st.—The anticlines are studied in detail for economical reasons;

2nd.—There are more typical horizons at the bottom of the system;

3rd.—The upper part of the system has no typical horizons, so that dislocations are hard to trace.

Transversal (dip) faults only occur on a small scale, but can be of importance for the mineralisation.

THE MINE SERIES ("SERIE DES MINES") AT AND NEAR KAMBOVE.

This series is composed of five well defined members, two thick (the bottom and the top ore), and three much thinner.

The bottom one is a thick bed of talcose dolomites, white or violet-pinkish, sometimes wholly metamorphosed into pure talc.

The relative movements of the overlying horizons have always taken place along this bed as sliding material. The thickness is difficult to estimate, but it certainly involves more than 300 feet. It is called the "FORMATION ARGILO-TALQUEUSE" I will call them "INFERIOR DOLOMITES."

There follows a thin, but for the identification of the "MINE SERIES" an important horizon. It is a thin-laminated cherty quartzite, called: "ROCHES SILICEUSES FEUILLETEES."

The laminae are on the whole not thinner than an eighth of an inch and alternately white and dark. The folding is remarkable, almost passing to crumpling, often leaving spaces between the layers. Thickness in Kambove 20 feet. On them repose the cellular quartzite ("ROCHES SILICEUSES CEL-

LULAIRES"), a band of wholly silicified cavernous dolomite without any stratification, 30 to 40 feet thick. They have often a very peculiar pagoda-form, which makes them a typical horizon in the Kambove region. But at other places they are different and only after a considerable field experience in the Katanga is one able to distinguish them from similar silicified dolomites in the higher series. A big block was photographed and is shown in plate No. 2.

Follows a band of dolomitic shales (flagstones) with alternating sandy layers. Kambove mine forms a transition of facies of these dolomitic shales, which are argillaceous in the Eastern and sandy in the Western mines. They include one or more layers of graphitic shales, also white at the surface. Thickness 150 feet. The top horizon is composed of dolomites, talcose and decomposed at the surface to grey sands.

In the sections I have divided them in two portions.

The bottom one is well stratified and includes layers of black chert with the aspect of the "ROCHES SILICEUSES FEUILLETEES," and silicified cavernous dolomites bearing a resemblance to "ROCHES SILICEUSES CELLULARIES." For a long time they were mistaken for these lower horizons.

The top one is very talcose and includes some white chert.

All these horizons were given names in the old days of mining in the Katanga and refer to the alteration facies of the beds. In depth they loose their surface character. The cellular quartzite becomes a finely crystalline dolomite with black dolomite crystals. The other horizons become crystalline dolomites with a more or less distinct bedding. They are difficult to distinguish in the cores of deep boreholes. According to VAN DOORNINCK, who describes in his book thin sections made of these dolomites in unaltered form, they all contain quartz and the silicification at the surface is at least in part due to the residual primary quartz.

The thin laminated and cellular quartzites often stand out in the field, forming the ridges of hills. This is also the case with the silicified dolomites of the horizon, but less so.

In Kambove the crests of the two long hills, which limit the mine to the North and the South, are formed by the outcrops of the cellular and thin laminated quartzites.

MINERALISATION.

Primary.

The primary ore, as we know it from the deep boreholes, occurs in the dolomites of the mine series as CHALCOPYRITE, possibly PRIMARY CHALCOCITE as copper ore, and CARROLITE (a sulphide of copper with traces of nickel) as cobalt ore. It occurs finely dessiminated and as veinlets following stratification and jointing planes of the whole of the mine series. Pyrite is always present in small quantities.

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No. 3. Shows the fault plane.

No. 4. Shows the contact of cellular quartzites (left) and dolomite shales at the left of the entrance (right).

The mineralisation seems to be due to ascending hydrothermal solutions of moderate temperature, which have traversed fissures existing almost to the top of the series. In my opinion the graphitic layers and there are probably more in the series than those in the dolomitic shales, play an important part in the reduction and precipitation of the mineralised solutions. The hypogene mineralisation was according to my view pre-overthrust. A direct relation with an underlying igneous rock is never observed. A few intrusions of basic rock (norite) exist in the centre of the basin, but there is no mineralisation in the surrounding strata.

Secondary.

The secondary mineralisation is very important and gives rise to the fabulous richness of the Katanga mines. A reduction zone of secundary enrichment in sulfides (cementation) hardly exists.

The primary copper ore, giving rise to supergene solution in the form of sulphates, reacted on the dolomites, forming copper carbonates (malachite, rarely azurite); on the quartz, forming the silicates (dioptase, chrysocolla, shattuckite, plancheïte, katangite.)

Copper oxides occur, mostly black oxides (tenorite CuO), less cuprite (Cu_2O). The black oxides are generally a mixture of iron, manganese, copper and cobalt oxides. The fact, that we find in several mines, also in Kambove, a great deal of the secundary (carbonate and silicate) ore to a great distance below the water level, shows an important rise of this level after the formation of those secundary ores.

As secondary ore the cobalt occurs always as black oxides. Erythrite, the arsenate of cobalt, has rarely been found.

As accessory ores we may consider the relatively small quantities of vanadium and uranium ores (the latter economically extremely important) and the precious metals (silver, gold, palladium.)

The impermeable brecciated talcose inferior dolomites prevented the descending solutions from migrating into the underlying rocks. In case of the series being overturned, the top talcose formation played the same part.

The Kambove Region.

It is obvious that the mine series, being at the bottom of the system, is exposed in the anticlines.

Although several anticlines occur (in an almost SSE.–NNW. direction), there is one, which has attracted the most attention, as nearly all the important mines of the Upper Katanga are situated in it.

A general feature of that anticline is, that the southern limb is thrust over the Northern one, along a fault plane gently dipping south and it is

there that the mine series is exposed. This is the case for the big mines: Etoile, Ruashi, Luushia, Likasi, Kambove.

In Kambove the southern flank is thrust so far over the northern flank, that a "Thrust nappe" is formed.

Coming from Panda to Kambove, the new road follows the axis of the syncline of Kisanga, which is shown on Map No. 3, annexed to this paper. The axis of this syncline plunges to the S-E., so that following the road to the N-W., one goes down in the series.

From the lower Kundelungu i.e. the series between the big and the little conglomerate, one passes a conspicuous outcrop of the Kakontwe limestone on which reposes a sedimentary limonite orebody, worked in the Kisanga mine. Just before the two limbs of the big conglomerate converge, the road turns to the north and traverses the big conglomerate perpendicularly.

Parallel to the road is the railway-cutting Kisanga-Kambove, showing a good section of the conglomerate and underlying N'Guya or M'Washia series, of which latter the banded shales, the graphitic shales and the oolitic cherty horizons are well exposed.

The Mwashia series is here separated from the mine series by a strike fault with talcose breccia, formed from elements of both series.

Going north one comes after crossing this breccia, into a hilly country with several outcrops of the mines series show on Map No. 4, and at about 2,000 feet north of this breccia, exists the breccia of the main fault, separating the overthrust nappe of the mine series from the underlying, though stratigraphically so much younger Kundelungu shales of the Kambove syncline.

The cross-section AB on Map No. 3, shows how these Kundelungu shales remain almost horizontal until the M'Sesa mine. Here one finds a little island of rocks of the mine series, identical with those of the Kambove mine.

Therefore I consider this mine as a "klippe" from the Kambove thrust-nappe. North of M'Sea, the Kundelungu shales are intensely folded with a general dip S-W. In the axis of the Kambove syncline several longitudinal breccias are observed, but for the reasons explained before, it is impossible to determine the importance of the dislocation. Probably the whole syncline may be considered as a synclinorium.

Towards the Mulungwishi anticline one goes down regularly in the series and meets the little conglomerate, and the Kakontwe limestone before getting to the big conglomerate, which forms the southern limb of the overturned anticline.

The Kambove Mine.

The general phenomenon of the above mentioned anticline is, that probably a vast area of overthrust of the southern flank has existed.

Large portions have been completely eroded, down to the underlying Kundelungu shales, and only patches are left.

All the mines mentioned before (Etoile, etc.) are situated in those remnants of the eroded nappe.

The Kambove mine occurs in the eastern part of the big overthrust area shown on Map No. 4.

The part of the overthrust, just south of the Kambove complex has been eroded, giving this complex its peculiar form, on three sides surrounded by Kundelungu.

The Kambove mine is limited to the N. and the S. by two long parallel hills, on which slopes, dipping from the mine, one finds Kundelungu shales.

The ridges are formed by the inferior quartzites i.e. the "Roches Siliceuses Feuilletees" and the "Roches Siliceuses Cellulaires." At the entrance of the mine the workings have exposed the complete succession. From both sides going from the outside towards the centre of the mine one finds: violet Kundelungu shales, brecciated Kundelungu shales, fault plane (photograph No. 3), brecciated inferior dolomites, the inferior quartzites (photograph No. 4), the dolomitic shales, etc. (photograph No. 5.)

The first impression is that we have here a regular syncline, but even a superficial examination of the centre of the mine makes this supposition impossible.

The workings are not sufficiently deep to explain the structure and therefore the geology of the whole mine has been a puzzle for many years. Only recently deep boreholes have been drilled in the southern part of the mine. In the beginning these holes gave no satisfaction as far as the geological structure is concerned, showing several quartzite layers, which all were taken for the inferior quartzites ("Roches Siliceuses Cellulaires" and "Roches Siliceuses Feuilletees.") To a great depth the rocks are completely decomposed, so that no core could be obtained; only a careful examination of the sludge and the sections exposed at the entrance of the mine, made it possible to distinguish the real cellular quartzite from the very similar strata in the superior horizon. Another step towards the solution of the general structure was, that after one or two repetitions of the mine series these boreholes passed into the Kundelungu shales.

Once we knew the existence of the two different quartzite horizons and the repetition of "Scales" of the mine series, a new interpretation of the northern and central less deep boreholes, was possible. This enabled us to

construct the geological sections of the mine, of which two typical ones are annexed (section 500 and 200.) Section 500 shows the existence of four overlapping scales of the mines series.

The upper one, the most northerly and the central one are partly removed by the excavation.

In the top one exists a small dislocation, along which the superior dolomites have moved a little along the black ore dolomite.

The outcrops of the cellular and thin laminated quartzites on the southern hill belong to the third scale. It was this one which gave the key to the structure.

The fourth one is intensely reduced in this part of the mine and is only shown in a few boreholes.

All the scales finish in depth in wedge shape, surrounded by a talcose mass of brecciated inferior decomposed dolomite, which has acted as sliding material.

Section 200 shows a similar feature, but the second or central scale, which was almost flat in section 500, is here folded in V form and the wedge form has disappeared by the excavation.

The lowest or fourth scale is better developed here and has also an outcrop in the southern hill.

Map No. 5 gives a birdseye view of the various scales, without indicating the horizons, only the whole scales, marked by different conventional signs. It shows, going from N. to S.: Kundelungu shales, then the main fault, separating the Kundelungu from the upper scale, of which the two parts separated by a little fault with north dip, are marked differently. Then follows a fault breccia also dipping, separating scale 1 and 2.

The second scale is divided in two portions.

The longitudinal axis of the mine forms arches and troughs and one of these arches has been cut by the excavation and shows the underlying breccia, which separates the second and third scales. For the same reason the bottom level of the ming shows "windows" of the third scale.

The third scale occupies the whole northern slope of the southern hill.

The fourth scale is only exposed to the south-east and is found there in depth in recent boreholes.

The eastern part of the "spoon" is brecciated, so that no regular structure is apparent.

The sections show that the four scales of the mine series lie in a hollow in the Kundelungu shales.

The dip of these shales round the mine show that the existence of a syncline is not probable.

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No 6 Shows the entrance of the mine seen from the N.-E

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No. 7. Shows the bottom level of the mine seen towards the N.-W.

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No. 8. Shows bottom level of the mine seen from the southern hill, to the right remnants of second scale.

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No. 9. Shows the talcose breccia scale No. 1 from scale No. 2.

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No 10. Shows the eastern portion of the second scale. Under the steam shovel is an outcrop of the dolomitic shales to be seen.

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No. 11 Shows in the left part, remnants of the cellular quartzite of the second scale.

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MAP No. 1.

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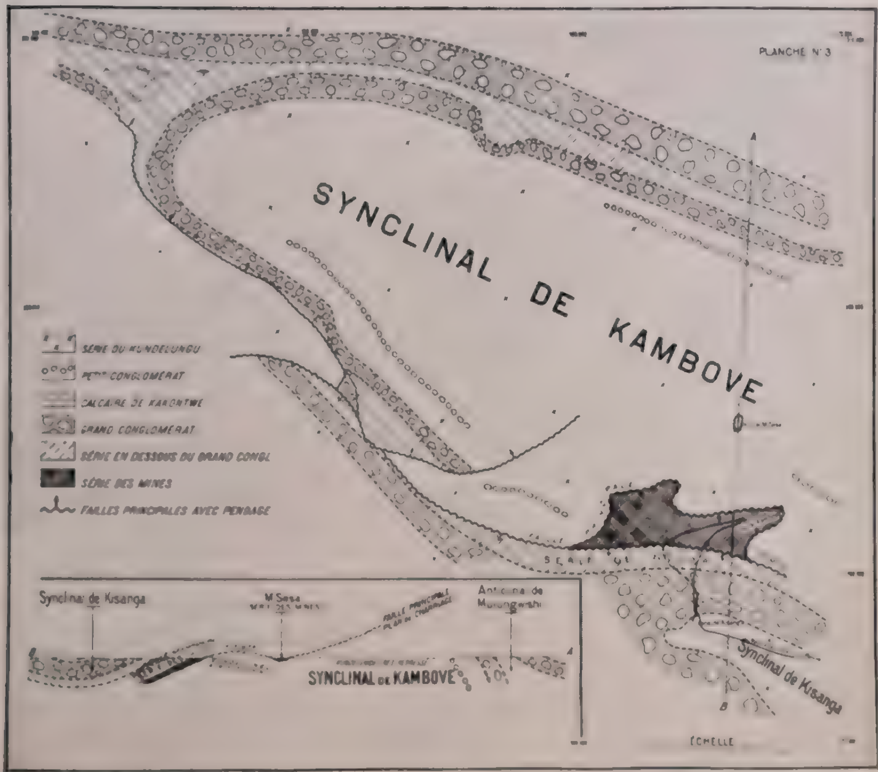
To follow page 452.



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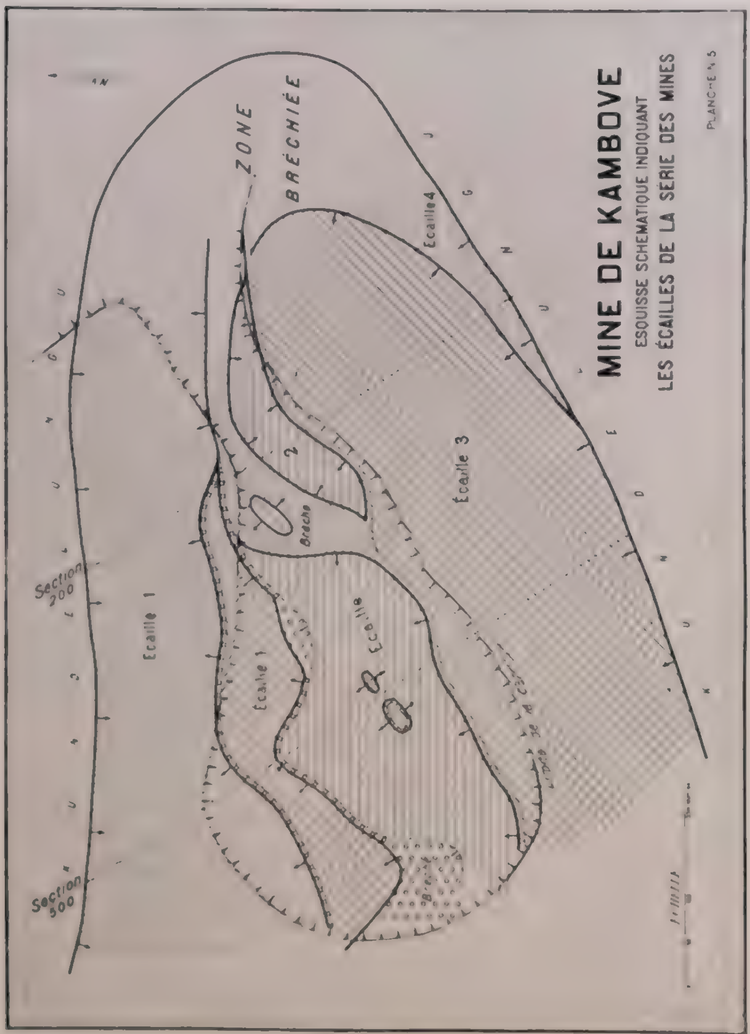
MAP No. 3.

To follow page 452.



Map No 5.

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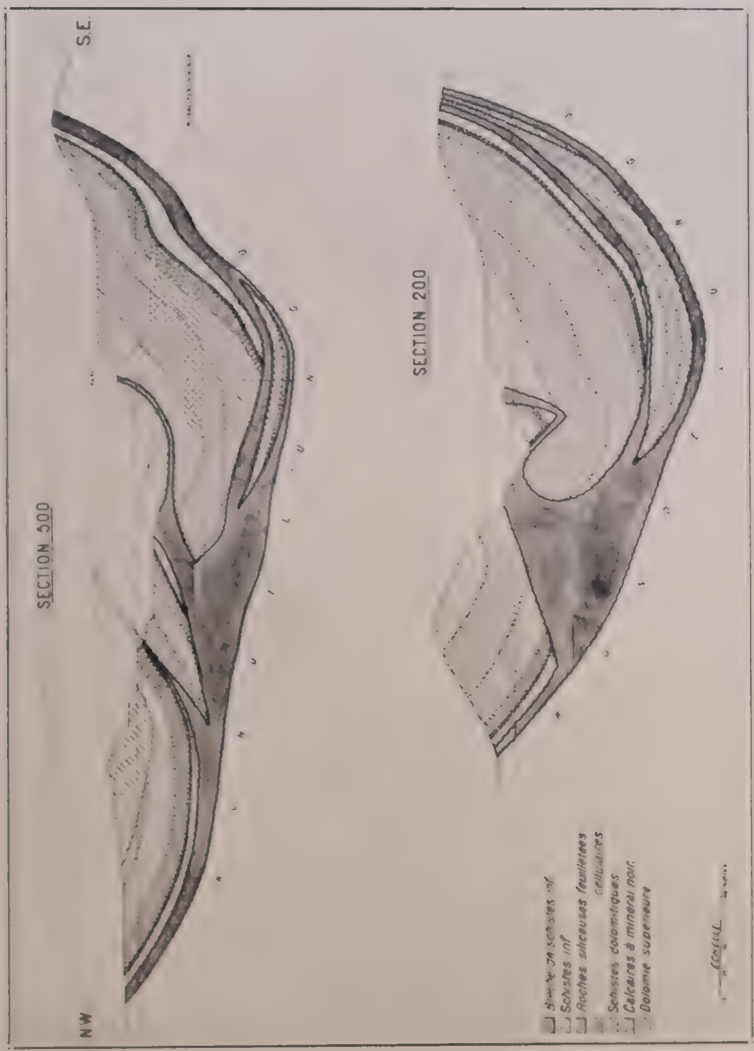
To follow page 452.



Geological sections Kambove Mine, compare Map No. 5.

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I do not know whether the hollow was formed before, during or after the overthrust, but it seems that a resistence of sufficient strength existed to the north of the mine to cause the wedging-in of these scales, one below the other, which resulted in this structure.

Mineralisation.

The mineralisation is secundary in the whole ore body of the Kambove mine and is almost completely composed of malachite and some chrysocolla.

It is hard to say which horizons have been the original orebearers, but now the mineralisation is generally limited to the cavernous quartzites and overlying shales (principally the cellular quartzite and also the quartzite in the black ore dolomite.)

The supergene solutions have moved down along the impermeable talcose breccias through these porous strata and have formed deposits of crusty malachite in the troughs. The ore in these quartzites has been completely leached out at the surface, leaving barren outcrops.

The second scale has been economically the most important and has already produced more than half a million tons of copper.

The third scale gives rich ore in depth at the bottom of the trough, far below the water level, and also the fourth gives an enriched zone in depth at the entrance of the mine.

50. ON THE GENESIS OF THE "KUROMONO" DEPOSITS.

BY

KAMEKI KINOSHITA.
(Geologist of the Imperial Survey of Japan.)

CONTENTS.

INTRODUCTION.

The "Kuromono" or Black ore deposit is a peculiar sort of ore deposit occurring abundantly and widely distributed in Japan. It forms irregular masses enclosed in the Tertiary sediments as well as the younger volcanic rocks such as liparite and andesite, with which it is in general genetically related. It is an intimate mixture of zincblende, galena, pyrite, chalcopyrite, etc., which form minute irregular grains.

The origin of the "Kuromono" deposit is one of the most perplexing problems of economic geology in Japan. Concerning its genesis, even after extensive studies by several investigators, opinions diverge. Some consider it as a syngenetic deposit while others as a epigenetic one. Some attribute its origin to a high temperature origin, while others to a low one. Among those who hold a syngenetic theory, there are some who try to explain it by a magmatic theory while there are some who propose a submarine sinter theory. Most of the investigators who hold an epigenetic theory unanimously accept a metasomatic theory. Concerning the temperature of ore-formation there are those who maintain a high one and a low one. The opinion of the former is again divided into three, viz. magmatic, pneumato-

litic and hydrothermal; the latter mostly adopt a hydrothermal theory, though there are some who try to explain it either on an acidic solution theory or on that of an alkaline solution. All of these opinions, so far as I know, are solely based on field evidences and not on studies with experimental methods.

The present paper is a brief summary of my studies on the genesis of the "Kuromono" deposits, in the field as well as in the laboratory.

The Temperature of the "Kuromono" Formation.

To know the temperature in which the ore was formed is one of the most important and interesting problems in the study of the "Kuromono" deposits, although it is a very difficult even to make a rough estimate.

In the "Kuromono" deposit, no high temperature minerals are found. On the contrary there are many low temperature ones, such as chalcocite, goethite, gypsum, barite, etc.

Chalcocite. The occurrence of chalcocite in the "Kuromono" deposit is rather rare and not great in quantity, but in some portion of the deposit, it is found as irregular specks in contact with bornite enclosed in chalcopyrite or pyrite. It is characterized by a greyish or bluish white colour, with the surface very smooth when seen under the microscope. It is almost contemporaneous with bornite in formation. Chalcocite and bornite are sometimes associated together making irregular intergrowths though more frequently they are developed separately as minute patches and streaks. Covellite, on the other hand, occurs always along the cracks and margins of bornite and chalcocite, although occasionally also along minute fissures found in the primary pyrite, chalcopyrite and zincblende. Therefore this covellite has doubtless been formed by a descending acid solution. Bornite and chalcocite, on the other hand, occur as irregular replacements of pyrite, chalcopyrite, etc., and not along the anastomosing channels of these minerals. Occasionally also they are found in the primary ore, deep below the so-called secondarily enriched sulphide ore zone as in the Wanibuch mine, Shimane Prefecture, reminding the observer of their primary formation.

Chalcocite is a dimorphous mineral. Commonly it belongs to the rhombic system, but at a high temperature crystallizes in the tesseral and exhibits the enantiomorphic transition point at 79° C.

The chalcocite in the "Kuromono" ore seems to always belong to the rhombic system, when judged by the direction of cleavage planes or the nature of etching figures. Of course, the transition temperature of rhombic and tesseral chalcocite may be more or less affected by pressure or some other factors, but it may be said at least that the chalcocite in the "Kuromono" ore has crystallized at a low temperature, say about 80° C.

Goethite. Ferruginous quartz is occasionally found in the "Kuromono" deposit, especially associated with chalcopyrite. Megascopicaly, it is a reddish brown compact mass, disseminated with cubic crystals of pyrite, about 3 mm. in diameter. Under the microscope, it consists of the intimate intergrowth of cryptocrystalline quartz and brown anhedral mineral, which has high indices of refraction and low double refraction. This brown mineral mostly exhibits a distinct pleochroism, the axial colour changing from brown to yellowish brown.

In most cases its crystals are too small for determining optical characters accurately, but in one specimen collected in the Hanaoka mine, Akita Prefecture, there were large crystals showing distinct interference figure of a biaxial nature. The apparent axial angle was not so large as that of limonite and it seems to correspond to that of goethite. In minute crystals also, the indices of refraction are not so high as those of hematite, but not so low as those of limonite, so that the mineral probably belongs to goethite.

According to the experimental study of Otto Ruff hydroxide of iron crystallizes out as limonite at a lower temperature than 42.5° C., but at 42.5° C-62.5° C it crystallizes out as a mono-hydroxide of iron, or goethite, and at a higher temperature than 62.5 C it crystallizes out as half hydroxide of iron or hydrohematite. Consequently the goethite found in the "Kuromono" deposit may have been formed at a low temperature probably between 42.5° and 62.5° C.

Gypsum and Anhydrite. In most of the "Kuromono" deposits there occur large masses of gypsum, close to, or at some distance from the ore body. In both cases, however, gypsum seems to have been formed almost contemporaneously with the "Kuromono." In the Manaoka mine, Akita Prefecture and in the Kano mine, Fukushima Prefecture, anhydrite occurs as the nucleus of massive gypsum, indicating that the former mineral has been crystallized before the latter.

According to VAN 'T HOFF, calcium sulphate crystallizes out of its aqueous solution at a lower temperature than 63.3° C as gypsum, but at a higher temperature as anhydrite, however this temperature is exceedingly influenced by the co-existent salt and when there are salts which lower the vapour pressure of the solution, the transformation temperature between gypsum and anhydrite is also lowered. For instance, when sodium chloride is present in the solution, anhydrite crystallizes out at a temperature above 35° C., and when magnesium chloride is dissolved even at 0° C.

The salts dissolved in the solution act to produce more vapour phase, as in the case of the raising temperature expending the hydride, on account of the increase of osmotic pressure and decrease of vapour pressure of the solution. Accordingly the co-existent salts do not generally raise the transformation temperature of the main salt. Therefore, the "Kuromono" ore

may be said to have been crystallized out of a solution at a lower temperature than 63.5° C.

Argentite. Some "Kuromono" deposits were formerly worked as silver sources, owing to the high contents of silver found in their oxidizing zone. The silver in the oxidized portion of the "Kuromono" ore, generally known as "Doko" or earthy ore, is mostly found in a native state, but in an unaltered portion as argentite.

Silver sulphide is a dimorphous mineral. At a higher temperature than 179° C., it crystallizes as rhombic acantite, but below it as a tesseral argentite. Therefore the occurrence of argentite in the "Kuromono" ore indicates that it has been crystallized out at a temperature below the transition temperature of these minerals.

As mentioned above, in the "Kuromono" deposits there are many minerals formed at a temperature lower than 100° C. Barite and calcite which are occassionally abundant in it, are generally recognized as low temperature minerals, and as there is no high temperature one ever found in the "Kuromono" the present writer takes the latter as having been formed at a temperature lower than 100° C., probably between 60 and 70° C.

The Nature of the Mineralizang Solution.

The "Kuromono" deposit contains a great quantity of barite, quartz, gypsum, etc., which are generally precipitated from aqueous solution, and there are no pneumatolytic or magmatic minerals, so that there is reason to believe that the deposit was formed from the ascending thermal solution. This opinion is accepted by most of our geologists. However, many different opinions have been proposed concerning the nature of the ore-forming solution, which, as the author believes, is so guessed at by the alteration of the country rocks as well as by the nature of the minerals contained in the deposit.

Alkaline Solution Hypothesis.

Concerning the nature of the mineralizing solution of the "Kuromono" deposit, it would be convenient to consider it from two different points of view. The one is the consideration from the alkalinity of the solution and the other from the degree of its ionization.

As a reason for assuming the alkalinity of ore-forming solution, there are many minerals in the deposit which can only be formed from an alkaline solution, such as pyrite and zincblende, while there is not a single one which can be formed from an acidic.

The propylitization of the country rock which is frequently associated with the "Kuromono" deposit is also generally accepted as an alteration by

the alkaline solution. On the contrary, the alteration by acidic solution such as alunitization has never been observed near the deposit.

Pyrite and Marcasite. Pyrite is one of the extensively distributed minerals in the deposit. It occurs as a constituent of "Keiko" (Siliceous ore), "Oko" (Pyritic ore) and "Kuromono" (Complex sulphide ore), and also granular crystals in massive gypsum. Pyrite in "Keiko" occurs as minute grains disseminated in the cryptocrystalline quartz, or as fairly large crystals in the microveinlets of quartz. It also occurs as the cementing material of the interspaces of granular quartz, in which case at the commencement of the mineralization, the pyrite fills up the minute cracks found in the quartz mass, then replacing the granular quartz of both sides of the cracks along the boundary of each quartz crystal, and lastly forming an irregular mass of pyrite. The pyrite in "Kuromono" or "Oko" always occurs forming crystalline grains which are cemented by other sulphite minerals such as chalcopyrite zincblende and galena. The pyrite in gypsum is also in the form of grains or crystals, and seems to have been crystallized prior to other minerals.

Marcasite occurs as a reniform or botryoidal aggregate facing a crack or druse in "Oko." In one sample taken from the "Doyashiki" deposit of the Hanaoka mine, Akita Prefecture, botryoidal marcasite was found encrusting the covellite which surrounds the chalcocite mass. This seems to indicate the secondary origin of the marcasite.

According to the experiments carried out by Allen and Crenshaw, the pyrite is the only mineral obtained in a crystalline form from the alkaline thermal solution, while the marcasite is obtained only from an acidic solution. So the deposit containing the primary iron disulphide, merely in the form of pyrite such as "Kuromono" may have been formed from an alkaline solution.

Zincblende and Wurtzite. Zincblende is an essential mineral of the "Kuromono" ore. It generally occurs in the form of minute grains with a diameter of 2-3 mm., disseminated together with galena in the interspaces of prismatic crystals of barite, or as forming irregular intergrowths with galena. But it also occurs in the massive gypsum, forming an irregular mass intermixed with other sulphide ores, or disseminated in gypsum showing banded structure caused by the alternation of the sulphidized and non-sulphidized portions. Zincblende in the gypsum mass is always granular and mostly belongs to an earlier generation than gypsum.

Wurtzite occurs as a reniform mass facing a druse in "Oko," associated with chalcopyrite, barite and galena, or as an encrustation on the crystals of zincblende. Rarely it forms bands alternating with those of marcasite; the bands being concentric or not. It is always found in druses or open textured parts of ore, and never found in the massive parts. From these modes of

occurrence, it may be inferred that the zincblende is a primary formation and wurtzite a secondary one.

According to the experimental studies of ALLEN and CRENSHAW, when the solution was strongly acidic no precipitation of zinc sulphide was observed, but when weakly acidic it precipitated as wurzite and when neutral or basic, crystallized as zincblende.

Calcite and Aragonite. Calcite occurs intimately mixed with zinc and lead sulphides at the marginal portion of the ore mass, or grown together with gypsum at the centre of massive gypsum. Aragonite occurs as nodules in the clay surrounding the "Kuromono" deposit, as in the Hanoka mine, Akita Prefecture, or as encrustation on the botryoidal marcasite and wurzite, as in the Yunosawa mine, Aomoria Prefecture. Aragonite of the latter locality is evidently secondary in origin, but that of the former may be looked upon as a primary formation.

Up to this time, many studies have been made to determine the condition in which calcite or aragonite is formed from an aqueous solution. Corcerning the acidity of the solution, H. WARTH says that from a basic solution aragonite only is precipitated, while from an acidic one calcite only. Besides, G. LINCK succeeded in obtaining aragonite crystals by adding a carbonate of alkali into a solution of the same composition as sea water. From these results, it seems likely that the occurrence of aragonite in the "Kuromono" deposit points to the alkaline nature of the ore-forming solution. This nature, however, is much influenced by the temperature and co-existing salts in the solution. Therefore, it is not possible to determine the nature of the mineralizing solution, simply by the presence of calcite or aragonite.

But the occurrence of calcium carbonate in the ore suggests that the mineralizing solution did not contain any strong acid such as sulphuric or hydrochloric.

Sericite. The so-called clay which abundantly occurs near the "Kuromono" deposit resembles a common clay at first sight, but under the microscope the one from below the oxiding zone does not show any character which an amorphous clay or cryptocrystalline kaoline would show, the greater part of it consisting of scaly or minute fibrous substance with beautiful interference colours. In other words, the so-called clay associated with the "Kuromono" deposit is not a common clay or kaoline, but an aggregate of sericitic minerals.

The sericitization or formation of potassium mica is characteristic of the rocks altered by an alkaline solution. In fact, sericite when acted by an acidic solution is deprived of its potassium into a kaoline like substance. Therefore, the so-called clay of the "Kuromono" deposits, which is mainly composed of sericite indicates the alkaline nature of the mineralizing solution.

It is noteworthy, however, that the clay in the oxidizing zone is not composed of sericite, in spite of the easy change of sericite into kaoline by descending acidic solution.

Propylitization. The propylitization which is frequently observed near the "Kuromono" is produced by the action of sulphuretted hydrogen or sulphide of an alkali, on it. This change is generally recognised as characteristic of the metsomatic action of alkaline hydrothermal solution.

The most remarkable change in propylitization is the chloritization of the ferromagnesian minerals and the formation of porphyroblastic pyrite.

An experiment to produce chlorite from some ferromagnesian minerals by the action of highly heated solution was made by G. FRIEDEL and F. GRANDJEAM. They succeeded in obtaining chlorite by making the caustic sodium and sodium alminic acid solution to react on pyroxene at a temperature of 550-570 C. The chlorite thus obtained can be decomposed by hydrochloric acid.

As previously mentioned, the pyrite can only be crystallized out of an alkaline solution. This mineral is sometimes very rare in propylite, a large amount of zeolite being found, as we see on the hanging wall of the Wanibuchi mine, Shimane Prefecture.

According to Lazarevicz, the pyritic propylitization is caused by a solution containing sulphuretted hydrogen or sulphide of an alkali, while the zeolitic propylitization is caused by a solution containing carbonic acid or carbonate of an alkali. W. J. MULLER and H KOENIGSBERGER succeeded in performing the synthesis of zeolite in an alkaline solution, and DAUBREE also recognised that zeolitization is one of the characteristic alterations by an alkaline solution. Moreover, as generally recognised, zeolite is easily decomposed by a strong acid solution. Therefore if we disregard the presence of pyrite or zeolite in propylite, the propylitization seems to be caused by the metasomatic action of an alkaline solution.

As previously mentioned, the "Kuromono" deposit contains many minerals which are only formed by an alkaline solution and also easily decomposed by an acidic one, no mineral formed by the latter being present. The silicification of country rocks or the occurrence of anhydrous silica as a gangue mineral is frequentiy observed in the ore deposit formed by an alkaline solution. Sometimes silicification gradually changes into sericitization or propylitization, and quartz occurs as a gangue mineral in all kinds of mineral deposits. Moreover, silica is deposited with several sulphides as at Steamboat Spring, U.S.A. From these facts, the writer concludes that the formation of "Keiko" (Siliceous ore) which is occasionally associated with the "Kuromono" ore also owes its origin to an alkaline thermal solution. Consequently, it is very probable that the "Kuromono" deposit as a whole was formed by the mineralization of an alkaline solution.

Colloidal Solution Hypothesis. The essential component minerals of the "Kuromono" deposit, such as galena, zincblende, pyrite, chalcopyrite, barite, gypsum, quartz, etc., are equally formed both from a colloidal solution as well as from an electrolytic. However, quartz, especially ferruginous quartz, barite, and opal are commonly precipitated not from an electrolitic solution, but from a colloidal. It is therefore, not impossible that the "Kuromono" was formed from a colloidal mineralizing solution.

Preparation of the Colloidal "Kuromono" Solution. In order to ascertain the possibility of the preparation of the colloidal "Kuromono" solution, the following experiment were undertaken by the present writer.

Two grams of a crushed sample of "Kuromono" ore from the Kosaka mine, Akita Prefecture, which had been through a 200 mesh sieve, were placed in a beaker with two liters of distillated water and twenty five cubic centimeters of caustic potassium solution. Then hydrogen sulphide gas was passed through them for several hours. Instead of caustic potash solution, potassium sulphide solution, or a mixed solution of potassium sulphide and caustic potash in equal amounts, was also tried in the above experiment. In both, the amount of potassium in each beaker was always kept constant and hydrogen sulphide gas always passed at same speed.

After one hour, in the solution of caustic potash, greenish gray dispersed particles of "Kuromono" ore were observed, while in the solution of the mixture of potassium sulphide and caustic potash, yellowish brown dispersed solution was obtained. In both cases, the amount of the dispersed particles in the solution was nearly equal, but in the potassium sulphide solution there was no dispersion at all.

Instead of a crushed "Kuromono" ore, a mixture of copper acetate, barium chloride, iron chloride, zinc chloride and lead acetate, was also taken in the experiment; in this case, in both kinds of solution the dispersed particles were observed dissolving the potassium sulphide and caustic potash respectively, though the dispersed particles were much more abundant in the latter.

The results of these experiments show the possibility of the colloidal nature of the mineralizing solution of the "Kuromono" deposit.

Comparison of the Alkaline and Acidic Colloidal Solution. As stated above, the formation of the colloidal "Kuromono" solution is possible, but it may be influenced by the nature of the solution in which the coagulation takes place. In order to examine this influence, a following experiment was made.

Two grams of a mixture of copper nitrate, chloride of barium, iron and zinc, and lead acetate were dissolved in equal quantities in 25 cubic centimeters of ammonia in one case, and in sulphuric acid of the same volume in another case, and through these solutions hydrogen sulphide gas was passed in the same way as before. After an hour, a dispersed solution was

found in the ammonia solution, but in the sulphuric acid solution no such dispersed particles were observed. This result suggests that the nature of the colloidal solution of "Kuromono" is probably alkaline, not acidic.

Relation between Ore Deposit and Country Rock. The possibility of the colloidal nature of the mineralizing solution of the "Kuromono" deposit, is explained not only by experiments but also by its geological occurrence.

Of the sixty four mines in our country, in which the "Kuromono" type is at present known to exist, forty six are found in tuff, twenty nine in shale, seventeen in liparite and seven in andesite. From this we see that most of the "Kuromono" deposits are found in tuff or shale, only some being in liparite and very few in andesite or a related rock.

Most of the Japanese geologists consider that the "Kuromono" deposit was formed by metasomatic action. However, many of these deposits are enclosed in a shale which is generally believed to be difficult to subject to metasomatism. But it may be explained by the fact that the shale possesses usually a strong coagulative power, which plays an important role in the genesis of the ore deposit.

The colloidal solution may be transported as long as it contains some dispersed agents, and coagulated agents are present. From this point of view an attempt was made to determine the relative coagulation effect of liparite, andesite, tuff and shale brought from several "Kuromono" mines.

Chips of each rock about 5 grams in weight were thrown into colloidal solutions of the "Kuromono" ore equal in weight and kept quietly at a room temperature for a long time. After twenty four hours, the colloidal solutions containing either tuff or shale was completely coagulated and became perfectly clear. But in the solutions containing either liparite or andesite, flocculence was observed only to some degree, though the coagulation had partly taken place. The coagulated substance adhered only to the surface of the rock chips without replacing them internally. From the result of this experiment the occurrence of many "Kuromono" deposits in the shale which is difficultly replaceable will be easily seen.

Form of the Ore Deposit. The form of the "Kuromono" deposit is various; the diameter of a large ore-mass may be several hundred or thousand metres, while that of a small one only a few centimeters. Most of them are massive, larger above and smaller below, showing a turnip-like shape, though rarely they are in bedded form. These forms may also be easily explained by the colloidal solution hypothis.

It is generally known that the colloidal solutions, especially metal and metal sulphide hydrosols, are made to coagulate by the change of the chemical and physical conditions, such as the change of temperature, addition of electrolytes, substraction of the dispersing agents, etc. The colloidal solution of the "Kuromono" are changed on heating gradually into a coagulated sub-

stance, first of a reddish then reddish brown and lastly when the greater part of the hydrogen has expelled, of a dark brown colour.

The hydrogen sulphide gas was probably present in the ascending mineralizing "Kuromono" solution. And if so, this gas may be abundant in the deeper horizon, but coming to near the surface it would escape owing to the diminution of the pressure. Then the coagulation of the colloidal solution would take place as a result of this escape, but the degree of coagulation will depend on the rate of the escape of the dispersing agent. As a consequence, the mineralization from the colloidal solution must be most strong near the surface or the crushed parts, where the hydrogen sulphide gas can easily be expelled, and most feeble in the deeper zones. Thus, the form of the "Kuromono" deposit, larger above and small below, can be explained as due to the difference of pressure dependant on the escape of the volatile dispersing agent from the colloidal solution. The bedded deposit, such as that of the Wanibuchi mine, Shimane Prefecture and the Yoshino mine, Akita Prefecture may result from the transfer of the dispersing agent along the sedimentation plane of shale, which is the country rock in these mines. In the Kano mine, Fukushima Prefecture, for the same reason, a part of the deposit covered by shale is bedded in form.

Structure and Texture of the "Kuromono" Ore. The "Kuromono" ore as already explained is an intimate mixture of zincblende, galena, chalcopyrite, barite, etc., but the proportion of these component minerals varies in its different parts. In some parts it assumes a black colour owing to the increase of zincblende, while in other where galena predominates it is grey. Still in other parts, the colour becomes yellowish on account of the increase of pyrite and chalcopyrite, and whitish when barite is abundant. Thus by the increase or decrease of the component minerals the ore becomes heterogeneous. Such a heterogeneous ore may be formed from the colloidal solution, because the phenemenon of diffusion is conspicuous only in the electrolytic solution and not in the colloidal. The colloidal solution even if it is diffused through some material, would be quite insufficient to prevent the formation of such heterogeneous structure.

Most of the "Kuromono" ores are aggregates of minute sulphide crystals, so arranged as to make a holocrystalline granular structure. The order of the crystallization cannot be determined. The intimately mixed nature of the ore is also explained by the colloidal solution hypothesis, because the precipitation will be greatest at those places where the volatile dispersion agents easily escape, or soluble or insoluble precipitations are met with in the solution. At such places the intimate mixture may be formed as a result of the contemporaneous crystallization of the component minerals.

Some "Kuromono" ore shows a micro-honeycomb structure, by the presence of minute pores. These pores may have been formed by the shrinkage of minerals in gel state due to their dehydration. A minute network of

veinlets in "Keiko" may also be due to the deposition of sulphide minerals in the shrinkage cracks of the colloidal silica.

Besides the characters stated above, we observe in the "Kuromono" deposit many minerals with a colloform structure, such as pyrite, zincblende, etc. A pyrite with colloform structure commonly occurs as spherules or a botryoidal aggregate with the diameter of about 0.5 mm. The inner part of the spherule is compact, its surface being covered with a thin crust. Some part of this crust shows a radial fibrous structure. Under the polarized light, the spherule changes the surface colour from blue to brown, following the rotation of the stage, and between crossed nicols it is deep indigoblue in one direction and yellowish brown in a direction perpendicular to the former. Such an iron sulphide evidently belongs to marcasite, but others do not show the radial structure and the colour also does not change in the polarized light. They may be pyrite.

Sometimes zinc sulphide also occurs as spherules with a concentric and radial structure. Such spherules group themselves together and present a crustified dome-shaped structure. Some of the zinc sulphide with a crustified structure is undoubtedly wurtzite, but others are isotropic between crossed nicols and perhaps belong to zincblende.

Rarely galena also shows colloform structure as is the case in the Yoshino mine, Akita Prefecture, where small crystals of galena are covered by a thin crustified one.

The colloform structure is best explained by deposition in the colloidal state. Such a structure may result on deposition from a true solution, but usually and most naturally it may be taken as an inheritance of colloidal solution.

Physical Properties of Component Minerals. The hardness and specific gravity of zincblende, pyrite, etc., with a colloform structure is somewhat lower than those of a crystalline substance, and the index of refraction of zincblende also shows the same relation. These characters are commonly observable in the minerals of a colloidal origin. For instance, a colloidal silica increases its specific gravity, hardness, refrective indices, etc., in proportion with the progress of crystalinity, as opal changes to quartz, with the intermediate stage of chalcedony. This change may be taken as a proof of colloidal origin.

Pleochroism is also feebler in the minerals of colloidal origin than in common crystalline ones. Some of the goethite contained in the ferruginous quartz, does not show any pleochroism, which may also be due to its colloidal origin.

Chemical Properties of the Component Minerals. A mineral formed from a colloidal state differs from crystalline one, not only in its physical properties but also in its chemical. For instance, colloform minerals show

a greater solubility than crystalline, owing to their greater adsorption surface caused by the isolation of mineral particles—by dispersion medium or the minute size of mineral particles even when they are crystalline.

As before mentioned, the "Kuromono" deposit contains many minerals with characteristic physical and chemical properties of colloidal origin, so that by assuming such an origin, its form and geological relation may also easily be explained. Then it will be seen that the assumption of colloidal solution is of a great help in the explanation of the "Kuromono" formation, although by so saying it is not the purpose of the writer to deny the possibility of an explanation by a true solution.

A moleculer solution is also undoubtedly of importance in the explanation of the genesis of "Kuromono" deposit so that we may say that the assumption of both kinds of solution is necessary for it.

The ore and gangue with a banded structure which are rarely found in the "Kuromono," gypsum, barite, quartz, etc., may be formed by the mutual reaction of two disperse phases in some cases, though more generally they may be made by the diffusion of true solution through colloidal media. If the degree of dispersion is high enough, the colloidal solution can also diffuse through, though slowly and with a decreasing velocity owing to the increased thickness of gel, which would act as a brake on the rate of diffusion. Thus the process will stop immediately and could not diffuse to a great distance. Therefore, ore and gangue with such a structure stated above, may be more naturally explained as a rhythmic precipitation due to the diffusion of moleculer solution in a gelatinous medium. Besides there are many evidences which suggest the diffusion of ore forming solution into the ore mass, so the true solution as the mineralizing one of "Kuromono" deposit is quite as important as the colloidal. Until now, however, the true solution only has been taken into account, and even at present the same thing hold good so there the writer is again forced to emphasize the possibility of the colloidal solution as the mineralizing solution of the "Kuromono" deposit.

Process of "Kuromono" Formation.

Concerning the origin of the "Kuromono" ore, two different opinions were hitherto proposed, viz. syngenetic and epigenetic hypothesis. However, in the Kosaka mine, Akita Prefecture, the deposit is found not only in a brecciated tuff forming the geological base of the mining district, but also in a liparite intruding into above tuff, as well as in another brecciated tuff unconformably covering these rocks. So it is obvious that the deposit was formed by an epigenetic process. Besides, the following characters seem to point out that the mineralization had taken place by metasomatic action :—

(1) Presence of complete or partly faced crystals in the foreign rock mass.
(2) Preservation of rock structures.
(3) Abrupt change of rock structure at the contact with ore.
(4) Absence of the concave surface.
(5) Presence of rock fragments enclosed in the ore mass.
(6) Peculiar outline of the ore mass.

Presence of Complete or Partly Faced Crystals in the Foreign Rock Mass.

Within the country rock or at the margin of an ore mass whose transition to the rock is gradual, idiomorphic crystals of sulphide minerals and barite frequently occur. Crystals which grow in cavities are attached to their walls or to other crystals of earlier deposition. Consequently their faces are never completely developed. The perfect crystal faces developed in the interstices between the grains of the original rock manifest an excellent criterion for the metasomatic origin of that mineral.

Crystals in Tuff. The tuff which occurs in the environs of the "Kuromono" deposit, is commonly made up of fragments of quartz and feldspar cemented together with a volcanic ash or a granular aggregate of quartz. Perfect crystals of pyrite and barite are often found in the tuff, embedded partly in one grain and partly in another mineral of the original rock. It is obvious that these crystals could only have been deposited by metasomatic action.

Crystals in Shale. In shale, newly formed crystals completely develop their faces by forcing aside or compressing the shaly material, because the exceedingly minute size of the component particles of this rock makes the above process possible. Accordingly the laminae of the shale frequently curve so as to surround the newly formed crystals. In some cases, however, new crystals cut across the lamination of the shale, in which case, it may be inferred that the mineral was formed by a metasomatic process.

Crystals in Liparite. Pyrite and barite also occur as idiomorphic crystals in liparite. Barite never occurs as a primary component of igneous rocks, so it is obvious that it has been formed by secondary action. Sometimes pyrite occurs as a primary component of liparite, but the one associated with the "Kuromono" deposit may belong to a secondary formation, because the crystals are thickly disseminated in the neighbourhood of a crack, then gradually lessening as they became distant from it. The fact that the pyrite possesses the crystalline form, and the transsection of the other constituent grains by one of the crystal faces of pyrite may show that it was formed by replacement.

Preservation of Rock Structures in Ore Mass. Some ores of the "Kuromono" deposit preserve their original rock structure and it may be taken as a proof of their metasomatic origin. The structure now under consideration widely differs. It may be easily observed in the field, or only recognised under the miscroscope. The kinds of structures are various. It may be primary, as stratified or phenocrystic structure, or secondary, such as brecciated. In "Keiko," structures were well preserved especially in the scarcely sulphidized part, but never in pure sulphide mass.

Stratification. In the ore deposit formed by the replacement of sedimentary rocks the stratified structure is frequently preserved in the ore mass. However, in the "Kuromono" deposit, such a structure is rarely found owing to the imperfect development of lamination or stratified structure of the tuff which occurs as the country rock of the deposit. But when the stratification in the country rock is plainly seen, the same structure is also preserved in the ore, which is then commonly called bedded or banded "Kuromono" ore.

In fact, some of the so-called bedded or banded "Kuromono" ores seem to have been formed by another process, though a part of it preserves its original structure. The ore preserving the stratified structure of the country rock always shows a conformable relation with the latter, the structure being continuous from one to another. On this account it is easily distinguishable from the ore of some other origin, but possessing the same structure.

The so-called bedded "Kuromono" of the Kosaka mine, Akita Prefecture, crops out near the Suruga shaft, close to the bottom of an open air pit, and dips eastward with an angle of about 35 following the inclination of "Keiko" found at its base. The thin bed of clay is intercalated between the massive "Kuromono" above and the bedded ones below. A laminated structure is well developed in the latter. Some of the laminae measure only one millimetre in thickness, though there are others thicker and the stratified structure is clearly visible even at a distance. There are cases in which the lamination considerably bends and suddenly reverses its dip. An ore with such a structure is the one in which pyrite is abundant. The most abundant mineral contained in such an ore is barite with pyrite, zincblende and galena next in quantity. It contains many rock fragments whose quantity and size considerably vary, and the bedded structure is shown by their regular arrangement within the ore.

Under the microscope, the ore contains everywhere angular fragments of rocks and shows a structure quite similar to that of a brecciated tuff and at first sight makes one think that the so-called bedded "Kuromono" of the Kosaka mine, Akita Prefecture is a portion of a stratified brecciated tuff containing a small quantity of minerals having the same structure as the tuff itself.

In the Hanaoka mine, Akita Prefecture, the writer also found a distinctly banded ore, composed of pyrite, zincblende and barite, in the overlying shale of the Doyashiki deposit. This ore has conformable relation with the shale and is distinguished from the banded ore of some other origin. Its boundary against the country rock is clear and distinct. It is also found in the joints of the shale running nearly at a right angle to the banded ore. Therefore it is quite clear that the banded ore of the Hanaoka mine has also been formed by an epigenetic process.

Pseudomorphs After Organic Remains. The kerogene shale which forms the country rock of the Udo mine, Shimane Prefecture, contains a great quantity of Globigerina shells. In some rock speciments collected near the ore mass, the shell of Globigerina was seen entirely replaced by pyrite, which indicates that the mineralization had taken place by a metasomatic process.

"Imoishi" or Taro-Shaped Ore. In the Yoshino mine, Yamagata Prefecture and the Kano mine, Fukushima Prefecture, elongated taro-shaped ores are occasionally found. They are called "Imoishi." The diameter is mostly 2-3 centimeters with the length varying from 10 centimeters to even 1 metre, though those longer than 20 centimeters are rather rare. The cross-section of these ores are generally circular, but in some elliptical, rarely irregular.

Regardless of the shape of the section, most of the "Imoishi" have rounded ends and look like taro, tough rarely branched ones are found. The constituent minerals are barite, zincblende, chalcopyrite, opal, etc. In some cases, the whole mass is formed by only one of these minerals covered with a thin crust of clayey substance, while in other cases, the two, either zincblende and barite or pyrite and chalcopyrite form the whole, showing a concentric structure.

The occurrence of "Imoishi" in the Yoshina mine is limited to the clayey shale called "Matsukawa-nendo" which form the hanging wall of that deposit, and in the Kano mine also its occurrence is limited to the shale. In both mines they are never found in the igneous rocks. Moreover, they do not occur in every part of the shale, being localized to some horizon, mostly with the inclination of about 45°.

Hitherto, it was said that the "Imoishi" are pseudomorphs after a branch of a tree, or a path of a thermal spring. If it is really the case, those after a tree-branch must lie more or less in horizontal position, and those after the path of a hot spring must stand more or less vertically. But most of them are inclined at about 45 and the mineralization is limited to the "Imoishi" themselves, the shale around never showing mineralization. From these facts the writer thinks that the "Imoishi" are pseudomorphs after calcareous nodules frequently found in the shale of these mining districts. Anyhow, they may be taken as one of the examples which preserve the original structure of the country rock.

Pseudomorph after another Mineral. In the country rock of the gypsum mass, found in the north western part of the Doyashiki deposit of the Hanaoka mine, Akita Prefecture, the writer found a feldspar crystal which was partly altered into gyspum. From this, it may be inferred that the gypsum is the product of metasomatic action on the felspar.

Preservation of Phenocrysts of Igneous Rocks in Ore Mass. Between the ore mass and liparite, the country rock of the "Kuromono" deposit, we frequently find an intermediate zone composed of a flint-like substance. This substance consists of a cryptocrystalline aggregate of fine granular quartz, in which we sometimes find tolerably large crystals of quartz which are corroded especially on rhombohedral faces. Such quartz crystals are also found in the "Keiko" of the "Motoyama" deposit of the Hanaoka mine, Akita Prefecture. They resemble the quartz phenocrysts found in liparite, so that it is highly probably that the corroded quartz crystals in "Keiko" are the remains of quartz phenocrysts in liparite.

Brecciated Structure. This structure is well developed in the brecciated tuff or volcanic breccia which contains many angular fragments of liparite, slate, quartzite, etc. When it is affected by the mineralization, at first it becomes disseminated with sulphide minerals, then afterwards, it is altered into ore mass as a whole. In a part where the breccia is perfectly mineralized, the original structure of the country rock can not be recognised, but in a portion only imperfectly mineralized the brecciated structure is frequently observed as in the Hata and Kosaka mines, Akita Prefecture, especially in the part affected where the silicification is most strong.

Abrupt Changes of Rock Structure at the Contact with Ore.

In general, the boundary between the ore and country rock is indistinct and passes gradually from the one to the other as in the case of "Keiko," but shows a sharp line of demarcation in the case of "Kuromono" or "Oko."

When the change is gradual, little can be learned from the intersection of structures; but when sudden all the structures will be abruptly cut off at the lines of intersection, as in the Takara mine, Yamanihi Prefecture. The liparite and tuff which are extensively found in the mine districts are remarkably broken into pieces in the vicinity of the ore deposit and exhibit a brecciated structure, but such a change of structure is not noticeable in the ore composed of sulphides, and the structure of the country rock abruptly changes at the boundary especially when it is in contact with a perfectly mineralized ore. The intersection of rock structures as above stated can only be explained either by a replacement or by deposition in a cavity or by magmatic injection.

It is not reasonable to take the "Kuromono" deposit as having been formed by magmatic injection or cavity filling; first because it is formed at a low temperature below 100° C., as already described, secondly because the ore mass of the Takara Mine measures 90 metres in a longer diametre, 55 metres in a shorter and 150 metres in a vertical; such a large cavity we can not think to have existed in an ordinary state of things. On these accounts the metasomatic action may have been the only process by which the deposit has been made.

Absence of the Concave Surface.—When a distinct demarcation line is found between the rock and ore, this line commonly indicates a concavo-convex surface. Such a surface is a characteristic type of boundary between the ore and rock when the former owes its origin to a replacement-mass.

Presence of Rock Fragments enclosed in the Ore Mass.—In the marginal portion of the ore deposit we frequently find the tolerably rounded fragments of a country rock only slightly affected by mineralization. In most cases these fragments are completely separated from the mother rock of which it was once a part by the surrounding ore.

It is obvious that in any open spaces, fragments of rocks can not remain suspended in the air unless there is something like an ore or ores to support them. Such an ore or ores can only be introduced by a replacement gradual in nature.

Peculiar Outline of Ore.—Under the microscope, pyrite, zincblende, galena, etc., of which the "Kpromono" ore is composed, fill up the interspaces of quartz or barite in the slightly mineralized portion, but the ore in the advanced stage of mineralization presents an arborescent appearance by the intrusion of the ore into the minute cracks of the country rock at both ends, thus giving the ore mass an irregular outline. This way of mineralization may also be only explained by replacement.

From what was stated above, the present writer concludes that the "Kuromono" deposit has been formed by the metasomatic action of the ascending thermal solution.

However, those who hold a different opinion may oppose this conclusion on the following grounds: (1) the rarity of drusy cavities in the deposit, (2) the occurrence of an ore with crustified structure, and (3) the presence of angular inclusions in the ore mass. But these may also be explained by replacement in some cases. When the replacement lessens the volume, drusy cavities are formed by metasomatism.

A crustified structure generally caused by cavity fillings, however, can also be formed by replacement on the surface of the metasome when the gradual change take place in the chemical composition of the ore-forming solution. The angular inclusions are also recognised at the beginning of the replacement in most of the metasomatic deposits. Therefore, the above

stated grounds are not enough to refute the writer's conclusion. It is most probable that the "Kuromono" deposit has been formed by the replacement of an ascending alkaline solution at a temperature 100° C.

Adsorption Metasomatism.

A metasomatic process in general seems to depend mainly on the process of adsorption taking place in the capillary interspaces of the rock particles, as well as on the oversaturation of the mineralizing solution. In the "Kuromono" deposit, the country rock is commonly altered into clay, and its adsorption may cause an important effect on mineralization. From this point of view, the studies on the relation between the adsorption substance and adsorbent becomes very important in the explanation of the "Kuromono" deposit. On this account, the present writer made some experiments concerning the adsorption of gypsum with the "Kuromono" ore.

The country rock of the gypsum deposit of the "Kuromono" type is always altered into a clayey substance at its contact place with the mineral mass, whatever kind of rock it is. In the case of common kaolinization, the content of CaO in the original rock is generally decreased, although the contrary is the case when the country rock is altered into a gypsum deposit just as is the case now under consideration. This is very important in explaining the genesis of the gypsum deposit, and may perhaps be dependent on the adsorption of the clayey substance. In order to ascertain this, the writer made the following experiment.

One gram of clay was placed in a beaker with 30 cc of $CaCl_2$ solution in various concentrations and kept quiet for several hours. After a certain time, the solution was filtered and the calcium precipitated as calcium oxalate. This precipitate was dissolved in sulphuric acid and the amount of oxalic acid was volumetrically determined by potassium permanganate solution. From the amount of oxalic acid, that of calcium was calculated from which the calcium chloride adsorped in the clay was determined.

The clay used in this experiment was a decomposed product of granite from Fujiyama-mura, Asa District, Yamaguchi Prefecture, having the following chemical composition:

SiO_2	Al_2O_3	Fe_2O_3	CaO	Mgo	Alkali	Total
61.20	18.07	9.01	0.96	0.37	9.84	99.45

The experiment was repeated twice, in the first one the beaker having been kept quiet during three hours and in the second one during eighteen hours, and the following results were obtained in each case:—

No. of Exp.	Concentration of Solution (1/1000 mol.)	18 Hours. Concentration of residual Solution (gr.)	18 Hours. Amount of Adsorption (% of clay.)	3 Hours. Concentration of residual solution (gr.)	3 Hours. Amount of Adsorption (% of clay.)
I.	0.005	0.009	0.8	0.0095	0.7
II.	0.010	0.021	1.2	0.025	0.8
III.	0.020	0.041	2.6	0.047	1.9
IV.	0.030	0.067	3.2	0.065	2.4
V.	0.040	0.092	4.0	0.096	3.6
VI.	0.050	0.108	5.9	0.121	4.6
VII.	0.065	0.135	8.1	0.162	5.8
VIII.	0.080	0.167	10.0	0.198	7.0
IX.	0.100	0.213	12.0	0.246	8.7
X.	0.170	0.263	16.9	0.321	12.3
XI.	0.160	0.304	23.0	0.444	18.0
XII.	0.300	0.549	45.0	0.612	38.7
XIII.	0.450	0.892	60.8	0.962	53.8
XIV.	0.640	1.439	69.1	1.492	60.1

From these results it is obvious that the amount of adsorption is exceedingly influenced by the time required for suffer the reaction. In order to ascertain this relation, 0.005 milimol solution of calcium chloride was kept quiet for different number of hours and following results were obtained:

	30m.	1h.	2h.	3h.	5h.	7h.	18h.
%	0.61	0.62	0.66	0.70	0.71	0.72	0.77

From the above it will be seen that the calcium chloride is absorbed by the clay.

If we pour a solution containing sulphuric acid on the clay with the absorbed calcium chloride, calcium sulphate is formed in the form of spherical aggregates or perfect spherulites.

When a solution either of $Na_2SO_4 10H_2O$ or of $CaCl_2.6H_2O$ is allowed to diffuse into gelatine containing the salt in converse in the diffusing solution, spherical calcium sulphate will be precipated. Near the contact of gelatine and solution a minute but dense aggregate is formed, while far from them a large and rough one. The distance of the spherulites from the contact place as well as their size is greater in the case when $Na_2SO_4.10H_2O$ is contained in the gelatine, than in the case when $Ca\ Cl_{22}.6H_4O$ is contained in it. In the former case, the largest spherulite measured two milimetres in diameters. If the concentration of the salt in gelatine is kept constant and diffuse the solution of various concentration in above experiment, the diffusion distance and size of the spherulites vary in proportion to the concentration of the solution. On the contrary, if the concentration of the salt in the gelatine varies while the concentration of diffusing solution is kept constant, the size of the spherulite varies proportional to the degree of concentration and diffusion distance inversely proportional to the same.

In one experiment, clay or Fuller's earth was also used instead of gelatine, and in another $NaCO_3\ 10H_2O$ in the place of $Na_2SO_4\ 10H_2O$ to obtain the precipitate of the spherulite of calcium carbonate. In both, a similar result was obtained.

Under the microscope, some of the precipitates obtained, consisted of a single spherulite, but others were composed of an aggregate of two or more. In either case, however, the central part of the spherulite was formed by the radial aggregate of the elongated crystals along c-axis, though peripheral part shows no regular arrangement. This structure quite resembles that of an aragonite from the Hanaoka mine, Akita Prefecture, or from the Matsushire mine, Shimane Prefecture, and suggests that aragonite also may be formed by a similar process.

The gypsum which is associated with the "Kuromono" ore is mostly found as nodules or massive, never showing a radial structure; on the contrary it is mainly composed of granular aggregate either of equidimensional hypidiomorphic crystals or of pseudo-porphyritic structure caused by the presence of tolerably large crystals of gypsum in the granular aggregate.

In the "Kuromono" deposit, the calcium carbonate is an earlier formed mineral than gypsum and we frequently find calcite partly replaced by gypsum. The absence of radial structure in the nodular gypsum is probably due to the fact that the gypsum is an altered form of the nodule of calcium carbonate.

The sulphide ore mass found in a clayey substance occurs also in a spherulitic form which owes its origin to the low solubility of metallic sulphide and the colloidal nature of the surrounding matrix.

Regardless of the nature of the ore, the formation of a spherulitic mass is characteristic of the colloidal state of the country rock, and the formation of "Kuromono" deposit has a close relation with the adsorption of the latter. The distribution of "Kuromono," "Oko" and "Keiko" may also be affected by the selective adsorption of ore and rock, due to their specific adsorption power. In short, the "Kuromono" deposit seems to have been formed not by a simple replacement, but by sort of adsorption metasomatism.

Summary and Recapitulation.

If anyone examines the relation between the "Kuromono" deposit and the country rock, he will find that the former is enclosed in two or more different kinds of the latter showing an unconformable relation with it, so that there is no doubt of the former having been formed by an epigenetic process. Moreover, (1) the presence of completely faced crystals in the foreign rock mass, (2) the preservation of rock structure in the ore mass, (3) the mutual intersections of rock structures, (4) the absence of the

concave-convex surface, (5) the presence of rock fragments enclosed in the ore mass, and (6) the peculiar outline of the ore mass, suggests the formation of the deposit by a metasomatic process. The country rock is commonly altered to a clayey substance in which the ore occurs as a spherulitic mass. This shows the significant effect on adsorption in the mineralization.

The "Kuromono" deposit contains many minerals which are commonly considered to have been crystallized out of an aqeous solution such as barite, gypsum, opal, etc. Hitherto no pneumatolitic mineral has been found. It also contains minerals of primary origin such as chalcocite, goethite, gypsum and anhydrite which were evidently deposited at a temperature below 100 C. Pyrite and zincblende which are the essential constituent minerals of the "Kuromono" ore, only crystallize out of an alkaline solution, and propilitization, sericitization and silicification of the country rock, which are frequently seen near the deposit are also alterations characteristic of the alkaline solution, while there are no mineral or rock alterations which may be ascribed to the acidic.

From what is stated above, the present writer concludes that the "Kuromono" deposit has been formed by the metasomatic action of an alkaline solution at a temperature below 100° C.

51. ÜBER BERGBAULICHE MÖGLICHKEITEN UND EINIGE WENIG BEKANNTE ERZVORKOMMEN IN DER TÜRKEI.

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Die Frage des Mineralreichtums der Türkei hat schon mehrfach die Literatur beschäftigt.[1] Trotz aller Untersuchungen, die vor, während und nach dem Kriege angestellt worden sind, ist aber diese Frage noch durchaus ein Problem, das von seiner Lösung noch weit entfernt ist.

Gewöhnlich hört man hierzu zwei Meinungen, die einander scharf widersprechen. Die eine rechnet mit reichen Schätzen, die dort zu haben sein. In diesem Sinne äussert sich vor allem die türkische Seite. Leider ist diese Auffassung nicht objektiv genug; vielmehr kommt in ihr eine Überschätzung des Wertes der einheimischen Bodenschätze zum Ausdruck, die man im allgemeinen als zu weitgehend und nicht den Tatsachen entsprechend bezeichnen muss. Die andere Ansicht spricht dagegen dem Lande grössere mineralische Reichtümer ab; eine Auffassung, die ihren Ursprung in den mannigfachen Enttäusschungen findet, die die Beschäftigung mit den türkischen Bodenschätzen schon manchem Interessenten bereitet hat. Damit scheint auch die Tatsache, dass es der Bergbau der heutigen Türkei bisher nur zu einer sehr bescheidenen Entwicklung gebracht hat, gut übereinzustimmen. Wenn man aber den Dingen näher auf den Grund geht, so gewinnt man doch den Eindruck, dass weder die eine noch die andere Meinung zu Recht gesteht, sondern dass die Wahrheit ungefähr in der Mitte zu suchen ist. In diesem Sinne hat sich kürzlich auch ein türkischer Bergingenieur in einem sachlich gehaltenen kurzen Aufsatz geäussert, dem man durchaus zustimmen kann.[2]

Es sind mehrere Gründe, die eine zuverlässige Beurteilung der nutzbaren Bodenschätze des Landes ausserordentlich erschweren: Zunächst und in erster Linie der sehr geringe Umfang der bergbaulichen Betätigung in der

(1) Vergl. hierüber u.a. Beyschlag. Der Mineralreichtum der Türkei. Z.f. prakt. Geol. 1918, S. 81. Krummer. Die türkischen Bodenschätze. Arch. f. Lag. Forschung 1928, H. 37.

(2) Nermy. Bergwirtschaft in der Türkei. Int. Bergwirtschaft 1927, S. 112.

letzten Zeit. Im ganzen handelt es sich um kaum mehr als 20 Objekte, die mit mehr oder weniger Erfolg bergmännisch ausgebeutet worden sind. Davon sind gegenwärtig—abgesehen von einigen unbedeutenden türkischen Betrieben—etwa 8 Werke in Betrieb: Das grosse *Steinkohlenwerk* der französischen *Heraclea-Gesellschaft* im pontischen Kohlenbecken; 2 *Manganerzbergwerke*, von denen das eine bei *Kepez* im Hinterlande von *Eregli* nahe der Schwarze-Meerküste, das andere bei *Makri* in Südanatolien gegenüber der Insel Rhodos liegt; 2 *Chromerzgruben*, diejenige von *Daghardi* in dem bekannten Chromerzbezirk der Provinz Brussa im Bereiche des kleinasiatischen Olymp, sowie ein neu in Bearbeitung genommenes Vorkommen in dem zuvor genannten Serpentingebiet von *Makri*; das bedeutende *Silber-Bleivorkommen* von *Balia-Maden* im nordwestlichsten Kleinasien; eine kleine *Quecksilberlagerstätte* in der Nähe von Smyrna; das bekannte *Borvorkommen* von *Sultan Tschair* südlich der Hafenstadt Panderma am Marmarameer (Pandermit.) Dazu kommt die zwar untersuchte, aber wegen Transportschwierigkeiten noch nicht in Angriff genommene grosse *Kupferlagerstätte* von *Arghana Maden* bei Diarbekir im armenischen Hochland, die in ihrer ausserordentlich reichen Zementationszone mehrere 100,000 t metallisches Kupfer enthält. Es handelt sich also—abgesehen von dem zuletzt genannten-durchweg um solche Vorkommen, die in dem am leichtesten zugänglichen westlichen Kleinasien in der Nähe der Küste oder doch nicht allzuweit von ihr entfernt, also unter relativ günstigen Transportverhältnissen gelegen sind.

Wie diese Aufzählung zeigt, ist der Rahmen, innerhalb dessen sich heute die bergbauliche Tätigkeit in der Türkei abspielt, in Anbetracht der Grösse des Landes ein sehr bescheidener. Leider wird das hierdurch gewonnene Bild auch durch die bisherige Untersuchungs- und Schurftätigkeit an den vielen sonstigen Mineralvorkommen nur wenig gefördert. Wohl ist vor allem im Kriege von deutscher Seite viel getan worden; aber von nachhaltigen Arbeiten, die eine zuverlässige Beurteilung der untersuchten Objekte gestatten würden, konnte damals natürlich nicht gut die Rede sein. Auch die jüngsten Untersuchungen, die im Auftrag der türkischen Regierung zum Studium der Eisenerzvorkommen des Landes von europäischen Fachleuten vorgenommen wurden, haben bezüchlich der Frage der Eisenerzbeschaffung zur Gründung einer nationalen Eisenindustrie noch durchaus keine Klärung gebracht.[3]) Dies ist verständlich, wenn man bedenkt, wie wenig gründlich die Prospektiertätigkeit in der Türkei von jeher betrieben worden ist.

So liegen die Verhältnisse fast überall und fast auf allen Gebieten noch gänzlich ungeklärt. Trotzdem wäre es verfehlt, dem Lande eine grössere Entwicklungsmöglichkeit auf bergbaulichem Gebiete abzusprechen, wenngleich die Schwierigkeiten, die dieser Entwicklung entgegenstehen, nicht zu

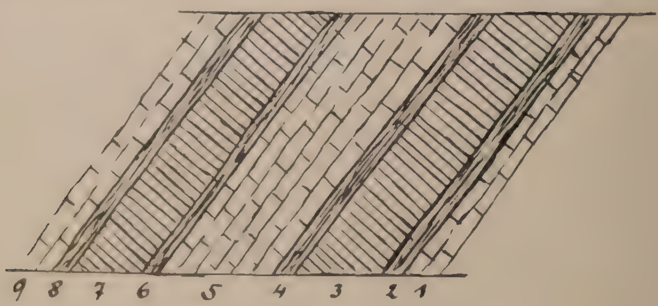
(3) Nowack. Die Frage der Eisenerzvorkommen in der Türkei. Z.f. prakt. Geol. 1928, S. 108.

unterschätzen sind. Diese liegen-abgesehen von der sehr mangelhaften Kenntnis der türkischen Bodenschätze—hauptsächlich in der veralteten Berggesetzgebung und dem Fehlen von Verkehrsmitteln. Ein grosser Teil der Konzessionen ist heute in Händen der Regierung, die sie zu Bedingungen, die vielfach in keinem Verhältnis zum Wert des betreffenden Objektes stehen, weiter vergiebt. So kann es geschehen, dass Vorkommen, die weder geologisch noch bergwirtschaftlich genügend untersucht sind, trotzdem mit so schweren Konzessionsbedingungen belastet werden, dass dadurch ihre gewinnbringende Ausbeutung von vornherein sehr erschwert wird. Indessen dürfte diese Praxis, die durchaus nicht im Interesse der Belebung der türkischen Bergwirtschaft liegt, mit der Einführung eines gegenwärtig in Vorbereitung befindlichen neuen Berggesetzes bald verschwinden. Ebenso wird z.Zt. auf dem Gebiete des Verkehrswesens viel getan durch den Ausbau der Häfen, die Erweiterung des noch sehr kleinen Bahnnetzes und durch Anlage fahrbarer Strassen. Es ist klar, dass hierdurch manches verkehrstechnisch ungünstig gelegenes Vorkommen in Zukunft der wirtschaftlichen Erschliessung nahegebracht werden kann.

Was nun die bergbauliche Entwicklung des Landes in der Zukunft betrifft, so wird man—abgesehen von der Kohle, die hier nicht behandelt werden soll—hauptsächlich der Entwicklung des Chrom-, Mangan- und Silber-Bleibergbaus eine günstige Prognose stellen dürfen. Beim *Chrom* liegen die Verhältnisse insofern günstig, als die meisten Vorkommen in guter Verkehrslage entweder in der Nähe der Küste oder im Bereiche fertiger bzw. im Bau befindlicher Bahnen sich befinden. Da die türkischen Chromerze früher auf dem Weltmarkte wegen ihrer guten Qualitäten zeitweise eine grosse Rolle spielten, darf man erwarten, dass eine systematische Beschürfung, an der es bisher noch sehr fehlt, zu einem neuen Wiederaufblühen des alten Bergbaus führen wird. Allerdings muss sich dieser der Eigenart der stark verzettelten und im allgemeinen nicht sehr grossen Erzkonzentrationen anpassen, dh. er muss beweglich eingerichtet sein.

Was die *Manganerzvorkommen* betrifft, so hat man diese—wie auch Krümmer (a.a.o.) mit Recht betont—eine Zeit lang stark überschätzt. Es hängt dies damit zusammen, dass man an vielen Stellen des Landes Manganerze von grosser Hochwertigkeit angetroffen hat. Da dieselben aber meist nur sehr oberflächlich beschürft wurden, so erweckten sie bezüglich der zu erwartenden Mengen vielfach ganz falsche Vorstellungen. Tatsächlich sind die meisten Lagerstätten klein, wobei die guten Erze gewöhnlich auf nesterartige Anreicherungen beschränkt sind. Sie eignen sich daher weniger als Rohstoffbasis für die Hüttenindustrie; wohl aber kommen einige von ihnen für einen Abbau im Kleinen zur Gewinnung von Braunstein in Frage. Die meisten dieser Vorkommen dürften als Verwitterungslagerstätten anzusprechen sein, bei denen es nur in der Nähe der Oberfläche zu einer beschränkten Konzentration hochwertiger Manganoxyde gekommen ist

Manganerze in grösserem Ausmass, die als Rohstoffquelle für die Hütteneindustrie in Frage kommen, gibt es wohl nur im südlichen Kleinasien in der Gegend des durch seine Chromerze bekannten Makri sowie weiter östlich an der Westseite des Golfes von Adalia bei Finika. Bei beiden Vorkommen handelt es sich um Erzsedimente von grosser flächenhafter Ausdehnung und flözförmiger bezw. lagerartiger Ausbildung. Besonders ausgedehnt sind die *Makri-Erze*, die neuerdings durch eine deutsche Gesellschaft in Angriff genommen wurden. Sie liegen frachtlich sehr günstig in unmittelbarer Küstennähe, sodass sie durch Drahtseilbahnen leicht abtransportiert werden können. Die Manganerzausbisse dehnen sich über eine Fläche von weit mehr als 100 qkm. aus. Davon kommt allerdings nur ein relativ kleiner Teil für den Abbau in Frage, da die Erzführung über die genannte Fläche nicht durchgeht, sodern in einzelne Teilstücke von grösserer oder geringerer Erstreckung zerfällt. Ursprünglich dürfte hier aber eine einheitliche sedimentäre Ablagerung vorgelegen haben, die später durch Faltung und Brüche zerrissen und zerstückelt sowie durch Erosion teilweise abgetragen worden ist. Die Träger der Lagerstätte sind dünnbankige Kalke, deren Alter wegen der Armut an Fossilien mit Sicherheit noch nicht feststeht; mutmasslich dürften sie aber der jüngeren Kreide bzw. dem älteren Tertiaer zuzurechnen sein. Das darin konkordant eingeschaltete Manganerzflöz zeigt dort, wo es ungestört vorliegt, fast stets das gleiche Profil (Abb. I). Es zerfällt in zwei Erzbänke von je 40-50 cm. Mächtigkeit, die durch ein kalkig-mergeliges Zwischenmittel von 50-100 cm. Stärke voneinander getrennt werden. Jede Erzbank besteht wiederum aus der eigentlichen Manganerzlage sowie aus 2 schwächeren Lagen von sogen. Eisenmanganerz, die das Manganerz auf beiden Seiten begleiten. Es entsteht so ein ungemein charakteristisches Profil. Die mittlere bauwürdige Mächtigkeit der beiden Manganerzbänke beträgt zusammen ca 60 cm.



Abbild 1.
1=Dünnbankige Kalke des Liegenden.
2, 4, 6, 8=Eisenmanganerzlagen.
3=untere Manganerzbank.
5=Zwischenmittel aus mergeligen Kalken.
7=Obere Manganerzbank.
9=Dünnbankige Kalke des Hangenden.

In mineralogischer Beziehung bestehen die Manganerzbänke aus harten dichten Manganoxyden von stückiger Ausbildung. Der Durchschnittsgehalt des Roherzes kann auf etwa 40% Mn. und 10-15% SiO_2 veranschlagt werden; dazu kommen stets mehrere Prozente Fe. Das Eisenmanganerz dagegen bildet ein gitterartiges Netzwerk harter Manganoxyde, dessen Maschen durch eisen- und kieselsäurereiche Rückstandsprodukte ausgefüllt werden. Das Ganze erweist sich hiernach als ein typisches sekundäres Umwandlungsprodukt der Oxydationszone. In der Tat haben die bisherigen Aufschlüsse gezeigt, dass die oxydischen Erze nach der Tiefe zu allmählich in ein sehr feinkörniges Gemenge von carbonatischen und silikatischen Manganerzen übergehen. Auch in dieser primären Zone zeigt das Flöz den characteristischen bankweisen Aufbau, nur mit dem Unterschiede, dass den Manganoxyden ein manganreicheres, dem sog. Eisenmanganerz ein manganärmeres, dafür aber eisenreicheres Material von carbonatisch—silikatischer Natur entspricht. Interessant ist, dass neben dem Mangancarbonat bzw.—Silikat auch in der Tiefenzone Manganoxyde auftreten, die ohne Zweifel primär sind und die mit ersteren in inniger Verwachsung vorkommen. Man kann hieraus den Schluss ziehen, dass schon während des Niederschlages des carbonatisch-silikatischen Erzes, der in seichtem Wasser erfolgt sein dürfte, eine teilweise Oxydation dieses Materiales unter dem Einfluss des Luftsauerstoffes stattgefunden hat.

Auch die manganerzführende Zone von *Finika*, die das westliche Küstengebiet der Bucht von Adalia umfasst, besitzt eine grosse flächenhafte Ausdehnung. Der erzführende Streifen, der in einem Grabenbruch liegt, hat eine Länge von etwa 30 km. bei einer mittleren Breite von ca 2-3 km. Indessen ist das Lager hier in sehr viele einzelne Teilstücke zerlegt, von denen nahezu 100 bekannt geworden sind. Die meisten derselben sind klein und kaum bauwürdig, sodass Finika nicht über die grossen Mengen verfügt wie Makri. Nur an einigen wenigen Stellen sind grössere Vorräte zu erwarten. Ausserdem ist hier der Flöztyp nicht so rein bewahrt wie bei Makri; vielmehr handelt es sich mehr um flachlinsenförmige Erzmittel mit stark wechselnden Mächtigkeiten. Bisher sind nur oxydische Erze nachgewiesen; wie sich die Erzführung nach der Tiefe verhält, ist unbekannt. Der Erzinhalt ist nicht ganz einheitlich; ein Teil der Erzbänke besteht aus sehr reinem hochwertigem Material, ein anderer Teil ist dagegen stark mit Kieselsäure verunreinigt und daher ohne Aufbereitung schwer verwertbar. Die reinen Erzbänke würden sich aber nach den vorliegenden Proben recht gut zur Gewinnung von Braunstein für chemische Zwecke eignen. Finika ist daher anders zu beurteilen als Makri. Während letzteres grössere Mengen Erze von mittlerem Mangangehalt für die Hüttenindustrie zu liefern vermag, dürfte bei Finika der Nachdruck auf die Gewinnung kleinerer, aber hochwertiger Erzmengen für Braunsteinzwecke zu legen sein, wobei aber auch viel ärmeres Erz zur Verhüttung anfallen würde. Im übrigen sind die geologischen Verhältnisse

ähnlich wie bei Makri, da die Erze auch hier dünnbankigen mergeligen Kalken kretazëischen bzw. alttertiären Alters zwischengeschaltet sind und wahrscheinlich ebenfalls syngenetischen Ursprung besitzen.

Das grösste Interesse unter den Erzvorkommen der Türkei beanspruchen gegenwärtig die *Silber-Bleierzlagerstätten.* Die einzige im Betrieb befindliche Grube Balia Maden hat sich dank ihrer reichen Erzverhältnisse rasch zu einem Grossbetrieb entwickelt, der in der besten Zeit jährlich bis zu 15000 t Werkblei von hohem Silbergehalt geliefert hat. Daneben sind aber auch einige der zahlreichen anderen Silber-Bleilagerstätten der Türkei als aussichtsreich zu bezeichnen. Dazu gehört vor allem *Bulghar Maden* im cilicischen Tarus. Es liegt nur etwa 10 km. Luftlinie von der Bagdadbahn entfernt an der nördlichen Abdachung des genannten Gebirges in ziemlich grossen Höhen von etwa 2000 m. und mehr. Die Erzführung ist an ein mächtiges Kalkmassiv von hohem geologischen Alter gebunden, das eine stark gefaltete Antiklinale bildet und ausserdem durch Brüche stark gestört ist. Besonders bedeutsam für die Erzführung sind die die Kalke durchsetzenden gangförmigen Eruptivgesteine, die als quarzführende Porphyre bezeichnet werden. In der Tat hält sich die Vererzung im grossen Ganzen im Bereiche der Porphyrdykes und folgt jenen vielfach unmittelbar, sodass man die Eruptivgänge geradezu als Wegweiser für das Aufsuchen der Erzmittel benutzen kann. Letztere treten in zweierlei Ausbildung auf: Einerseits folgt die Vererzung den Schichtflächen des Kalksteins, ist also lagerartig. Andererseits sind die Erze häufig auch auf Klüften abgesetzt worden, die die Schichtung quer durchschneiden. Durch Erweiterung der Klüfte und Schichtfugen sind nicht selten grosse Hohlräume von gewaltiger Ausdehnung entstanden, die z. Tl. mit Erzen ausgefüllt sind. Ausserdem ist auch der angrenzende Kalkstein selbt mehr oder weniger stark mit Erzen imprägniert worden. Räumlich betrachtet besteht die Vererzung aus einem System von unregelmässig-linsenförmigen bzw. stockförmigen Erzkörpern, die im Streichen und Fallen sehr regellos aneinandergereiht sind. Die Länge der vererzten Zone beträgt—sofern man auf Grund der alten Arbeiten ein Urteil fällen kann—mindestens 5-6 km. die vertikale Bauhöhe über 300 m, geht aber wahrscheinlich erheblich darüber hinaus.

Der alte Bergbau bewegte sich bisher ganz in den oxydierten Lagerstättenteilen, wo neben Bleiglanz bedeutende Mengen von Bleicarbonat, untergeordnet auch Zinkerze, vorkommen. Das Bleierz zeichnet sich durch ungewöhnlich hohe Edelmetalgehalte (vorwiegend Silber, untergeordnet Gold) aus, sodass der Edelmetallwert des erzeugten Werkbleis schätzungsweise etwa ebensohoch ist wie der Bleiwert. Hierin sowie in der anscheinend grossen Menge an verfügbaren Erzen beruht der Hauptwert des Vorkommens. In genetischer Beziehung handelt es sich um eine echte hydrothermale Erzlagerstätte, die teils durch Hohlraumfüllung auf Klüften und Schichtfugen,

teils durch unmittelbare metasomatische Verdrängung des angrenzenden Kalksteins entstanden ist.

Über die sonstigen Silber-Bleivorkommen Kleinasiens ist fast nichts bekannt. M.E. verdienen aber vorallem die Lagerstätten des pontischen Erzgebietes im N des Landes besondere Beachtung, da hier z.Tl. ähnliche geologische Verhältnisse vorliegen wie im W und S: dh. vererzte Kalkmassen im Bereiche von Durchbrüchen jungvulkanischer Gesteine. Von dieser Art ist zb. auch das uralte Vorkommen von *Gümüsch-Hadjiköoj* in der Nähe der Stadt Mersivon, das grosse Ähnlichkeit mit Bulghar Maden besitzt. Das dortige Kalkmassiv, das vermutlich der oberen Kreide angehört, ist in der Nähe von Andesit-Durchbrüchen von einer Unzahl alter Arbeiten förmlich wie besät, die zwar meist klein sind, dafür aber in die vielen Hunderte gehen. Stellenweise stösst man auch auf grosse Pingen bzw. Pingenzüge, die den Schluss zulassen, dass die Alten dort unterirdische Weitungsbaue auf besonders stark vererzten Zonen angesetzt haben. Dass dem Objekt eine grössere Bedeutung zukommt, beweisen auch die grossen Schlackenhalden aus früheren Zeiten, die auf etwa 200000 t geschätzt werden können. Leider liegt die Lagerstätte, die völlig verbrochen ist, z.Zt. noch gänzlich brach, obwohl die Verkehrsverhältnisse durch die Fertigstellung der kürzlich eröffneten Bahnlinie Samsun-Amasia wesentlich günstiger geworden sind.

Die angeführten Beispiele zeigen, dass die kleinasiatische Türkei, die nahezu doppelt so gross ist wie das heutige Deutschland, auf bergbaulichen Gebiet nicht von vornherein abfällig beurteilt werden darf, sondern erst einmal einer gründlichen Durchforschung seiner erzführenden Distrikte bedarf. Hierbei wird sich sicher manches der bis jetzt namentlich bekannten Erzvorkommen als wertlos erweisen. Anderseits ist aber nicht daran zu zweifeln, dass eine systematische Untersuchung manche kaum bekannte bzw. wieder vergessene Lagerstätte ans Tageslicht bringen wird, die auch für das europäische bzw. amerikanische Kapital einen genügenden Anreiz zur wirtschaftlichen Betätigung zu bieten vermag.

52. LES MINÉRALISATIONS CUPRIFÈRES DE LA ZONE FRONTIÈRE KATANGA-RHODÉSIE.

PAR

J. THOREAU,
Professeur á l'Université de Louvain.

L'intérêt présenté par les gisements de cuivre du Sud-Katanga et de la, zone voisine de la Rhodésie du Nord, tant au point de vue économique qu' à celui du problème de la genèse des concentrations cuprifères, qui comptent parmi les plus riches du monde, nous engage à résumer pour le Congrès de Prétoria les résultats d'une étude micrographique que nous avons eu l'occasion de faire des minerais du gisement de Kipushi au Katanga, tout proche de la frontière (Sud-Ouest d'Elisabethville.(1))

Le gisement, encaissé dans des strates sédimentaires où les calcaires prédominent (série schisto-calcaire, terme supérieur des formations à plissements prononcés du Congo), se trouve en rapport très net avec une fracture faille remplie par une brèche chloriteuse (2): ces conditions indiquent déjà une origine métasomatique, à l'intervention de solutions métallifères amenées par la faille. L'étude micrographique est venue confirmer l'hypothèse d'une formation par " replacement " du à des solutions hydrothermales d'origine magmatique.

Les minerais étudiés, extraits de sondages, proviennent de la zone primaire et de la zone de cémentation du gisement. Ils comprennent comme constituants primaires les sulfures communs, pyrite, blende, tétraédrite, chalcopyrite, bornite et galène, et comme produits d'enrichissement secondaire la bornite, la chalcosine, la covelline et un peu d'argent natif.

Les observations faites sur de très nombreuses sections polies ont permis de fixer comme suit l'ordre des cristallisations hypogènes: à une première période de formation des minéraux de gangue, calcite et dolomite d'abord,

(1) L'étude détaillée, accompagnée de nombreuses microphotographies, a paru dans les *Mémoires de l'Institut Géologique de l'Université de Louvain*, Tome IV, 1928.

(2) Voir J. THOREAU. Observations lithologiques sur une Brèche chloriteuse de la Région des Gisements de Cuivre du Haut-Katanga. *Ann. de la Société Scientifique de Bruxelles*, Tome XLV, 1926, p. 302.

puis quartz-feldspath-muscovite-chlorite, ont succédé les minéralisations sulfurées. Commencées par la pyrite, dont la période de formation chevauche en partie celle du quartz, ces dernières comprennent, après le dépôt du sulfure de fer, une phase zincocuprifère au sein de laquelle les divisions sont malaisées à établir; la blende n'est jamais postérieure aux sulfures de cuivre, mais parmi ces derniers la chalcopyrite et la tétraédrite paraissent s'être formées, pour une bonne part, en même temps que le sulfure de zinc, tandis que la bornite hypogène lui est généralement postérieure. Enfin la galène, bien que couvrant pour une partie la fin de la période zinco-cuprifère, apparait comme le minéral le plus jeune.

Notons encore que la bornite hypogène ne se rencontre pas en même temps que la pyrite; c'est la chalcopyrite qui accompagne normalement le sulfure de fer. La pyrite, formée en premier lieu, aurait donc influencé la nature du sulfure cuprifère. Une observation analogue a été rapportée pour un gisement de cuivre de l'Arizona. [1]

Les minéraux d'une phase tendent à épigéniser ceux de la phase précédente. L'observation ne prête à aucun doute, par exemple, pour la blende ou la chalcopyrite vis-à-vis de la pyrite, ou encore pour la bornite vis-à-vis de la blende: on voit le minéral de première formation rongé par le minéral nouveau et ne plus présenter souvent que des vestiges à contours déchiquetés au sein des plages de ce dernier.

A côté de ces textures à signification claire, il en est d'autres d'interprétation difficile. On sait que des phénomenes fort différents peuvent donner naissance à des textures apparemment identiques, telles les inclusions distribuées suivant des directions cristallographiques d'un minéral, ou les interpénétrations en filets parallèles, et qui peuvent être dues soit à une démixion à partir d'une solution solide, soit à une action de métasomatose. J'ai cru devoir interpréter dans le premier sens des inclusions régulières, de très petites dimensions, de chalcopyrite au sein de la blende, tandis que des intermélanges en filets parallèles de bornite et de chalcopyrite, en bordure des grandes plages de chalcopyrite, se révèlent dues à une épigénie de la chalcopyrite par de la bornite supergène.

Le cas de la démixion prouve que la minéralisation a eu lieu à une temperature assez élevée, que nos connaissances sur le systeme physico-chimique blende-chalcopyrite ne nous permettent malheureusement pas de préciser.

Les textures à "mutual boundaries" et les textures graphiques ont été considérées, à défaut de preuves contraires, comme indicatrices d'une formation simultanée des composants.

Sans vouloir préjuger de l'origine de tous les gisements de cuivre du Katanga et de la Rhodésie du Nord, en particulier de ceux où la localisation

[1] M. N. Short and I. A. Ettlinger. Ore deposition and Enrichment at the Magma Mine Superior, Arizona. *Trans. of the Amer. Inst. of Min. and Metall. Engin.*, No. 1552, février 1926.

parfaite des minerais dans certaines strates suggère, et appuie à première vue, l'hypothese sédimendaire, il me parait opportun d'attirer l'attention sur l'existence de minéralisations avant les caractères de minerais filoniens: l'ordre des dépôts y est conforme à celui que l'on observe dans un grand nombre de gîtes du monde, dont l'origine magmatique est unanimement admise, et certaines textures révèlent une température de formation assez élevée.

Mais la formation des concentrations cuprifères de l'Afrique Centrale pourrait couvrir une longue période de temps géologique et revêtir de ce fait un caractère complexe: des gîtes sédimentaires dérivés des premiers coexistent peut-être, et des remises en mouvement accompagnées de migration dans les terrains encaissants ont pu se produire. Il importe donc de rechercher séparément pour chaque gisement le mode de formation qui lui est propre. Nous tenons celui de Kipūshi comme d'origine magmatique directe et mésothermal.

53 OBSERVATIONS ET HYPOTHÈSES SUR LES RAPPORTS DU RIF, DE LA CORDILLERE BÉTIQUE ET DE L'ATLAS.

PAR

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SUESS admettait (1) que les plis alpins ayant traversé la Méditerranée par l'Est de la Corse, la Sardaigne, les Baléares, atteignaient la Cordillère Bétique, puis se réfléchissaient dans le Rif, venant se réunir avec les plis atlasiens et par là avec l'Apennin. Plus tard GENTIL montra (2) qu'il faut admettre qu'une partie des plis atlasiens plonge dans l'Atlantique vers le cap Ghir. Récemment, Mr. ARGAND a modifié la vue de Suess, en admettant (3) que les plis du Rif, primitivement parallèles à ceux de l'Atlas et prolongeant la Cordillère bétique vers l'Ouest en Atlantique se sont ensuite repliés vers le S.E., formant la boucle que nous connaissons dans le Nord du Maroc. Enfin, tout récemment, Mr. STAUB a cru devoir faire ressortir (4) l'invraisemblance de cette boucle qui serait, dit-il, le seul cas connu de chaîne eurasiatique offrant une telle "inflexion d'axe." Les observations de MM. TERMIER et MAURY confirment la continuité des Alpes avec la Corse (5) et la montrent avec la Sardaigne, les Baléares et la Cordillère bétique.

Il convient donc de savoir si le Rif est vraiment une chaine alpine incurvée, venant buter contre les plissements de type apennin des chaînes atlasiennes; si, une partie des plis bétiques se continuant vers l'Algarve et l'Atlantique, il faut voir dans le Rif une chaîne née par virgation des plis bétiques et mourant dans l'Est du Pays de Melilla, ou au contraire une carapace, (Deckenkarapace, dit Mr. STAUB) venue depuis le pays bétique jusqu'au Maroc en chevauchant les régions actuellement effondrées où se montre Alboran, ou enfin si le Rif est un fragment de la série appenine qui est plus méridonale que lui et s'il se rattache à l'Atlas.

Les divers auteurs qui jusqu'à présent se sont occupé de cette question ont, semble t'il, négligé le point le plus important avant toute description géologique: étudier sur place le pays que l'on décrit. Seul Mr. STAUB s'en est approché: je veux dire qu'il est venu à Tanger, qu'il a examiné les abords du détroit de Gibraltar et la Cordillère Bétique en grande partie, mais *il n'a*

pas traversé le Rif, et les circonstances veulent qu'au moment où j'écris ces lignes, je suis le seul géologue ayant traversé du détroit Sud Rifain à la Méditerranée la série plissée du Rif.

Aussi puis je me croire apte à donner sur ce pays quelques résultats d'observations directes.

I) La plus importante, à mon sens, de ces observations, est celle qui m'a permis de constater qu'il n'existe *aucune liaison* entre les plissements du Rif et ceux de l'Atlas.

Depuis la région de Meknès et Fès, si minutieusement étudiée par Mr. DAGUIN (6) jusqu'à la plaine des Triffa, décrite jadis par L. GENTIL (7), s'étendent une série de couloirs plus ou moins larges qui méritent d'être observés de près. A l'Est de la région de Fès, se montre le couloir de l'Innaouen où les plis du Prérif viennent déferler sur le pays tabulaire qui borde au Sud cette vallée et s'élève jusqu' aux anticlinaux du Moyen Atlas dont le plus NW a été décrit à quelque distance de là par Mr. BEAUGÉ (8). Bientôt nous atteignons le col de Touahar où, sous le Jurassique tabulaire, apparait un massif paléozoïque sur quoi s'écrasent les plis rifains les plus antérieurs. Puis nous atteignons Taza et, là, les plis rifains viennent au contact des plis du Moyen Atlas, mais ce contact par contiguité ne peut jamais induire en erreur et faire croire à une continuité. Alors que les plis rifains sont fortement couchés, écrasés et laminés, ceux du Moyen Atlas avec lesquels ils viennent en contact sont des plis droits ou à peine déversés et de style totalement différent de celui des premiers que l'on voit absolument indépendant d'eux. D'ailleurs, dès après Taza, le contact cesse et les plis du Rif courent vers le Nord, alors que les plis de l'Atlas vont s'ennoyer sous la plaine de la Moulouya en courant vers le NE. Entre ces deux séries de plis, reparait le pays tabulaire, avec des fractures donnant naissance à des phénomènes volcaniques. Ce pays tabulaire se poursuit par les pays des Beni Bou Yahi, Oulad Ahmou Raho, Oulad Abdallah, et la plaine des Triffa jusqu'à la Mer Méditerranée.

Ainsi, dans toute l'étendue où le Rif et le Moyen Atlas se trouvent au voisinage l'un de l'autre, nous les voyons constamment séparés par une zône tabulaire, parfois recouverte entièrement par les plis couchés rifains mais dans des conditions telles que *jamais il n'est possible de voir une continuité se substituer à la contiguité entre le Rif et l'Atlas.*

Le Rif et l'Atlas sont donc indépendants.

II) Outre cette indépendance marquée par la zône tabulaire qui les sépare, le Rif et l'Atlas offrent aussi d'autres raisons d'être tenus pour indépendants. Le style de plissement dont j'ai déjà dit un mot, et qui, dans le second est surtout un style de plis droits ou à peine couchés, cheminant au milieu de synclinaux à fond plat, et se dressant brusquement au

milieu de plateaux, est au contraire dans le premier un style de plis couchés étirés de façon à former des nappes du premier genre et même souvant des écailles. Des marnes schisteuses fortement laminées transformées par la translation de manière à prendre le faciès lustré, des quartzites provenant de grès laminés, des micaschistes, des schistes séricíteux, avec accompagnement de roches vertes, de gabbros, de serpentines, se montrent dans le Rif, alors que *jamais de telles manifestations de compressions et de métamorphisme ne se montrent dans le Moyen Atlas.* Ces plis glissent sur un substratum plastique de Trias qui forme au pourtour et dans l'intérieur du Rif et du Prérif des bourrelets argilo-gypso-salins au contact des nappes et des écailles entre elles. Un tel substratum plastique n'est pas entré en jeu dans l'Atlas. Au contraire, nous retrouvons dans le Rif tout le style de la Cordillère bétique. *Le Rif présente donc de nombreuses analogies avec la Cordillère bétique comme constitution et type de plissement.*

III) Les plis de la Cordillère bétique, contrairement aux affirmations de Mr. Staub, ([9]) franchissent le détroit de Gibraltar dans des conditions telles que *tous* les anticlinaux, que j'ai observés vers Tanger dans les coupes naturelles offertes par les oueds se dirigent vers le nord et reparaissent sur la côte espagnole entre Tarifa et Gibraltar. L'erreur qui consiste à nier ce passage est d'ailleurs facile à faire, car des phénomènes de dissolution des argiles sous jacentes aux grès de l'Oligocène (Arenisca del Aljibe) et un ennoyage par abaissement d'axe sous le détroit peuvent faire croire à un synclinal sur le détroit même. Toutefois l'examen des anticlinaux profonds montre que ce ne sont là que des apparences illusoires. Il y a continuité des plis entre Tanger et Tarifa. Et *si la portion la plus externe de la Chaine bétique se dirige bien, par l'Algarve, vers le Cap Saint Vincent, sa portion la plus interne au contraire vient à partir de Cadix se réfléchir vers le Sud et gagner le Rif.*

IV) Des phénomènes volcaniques se manifestent sur la côte rifaine (volcan de la pointe des pêcheurs), montrant des phénomènes de fracture sur le bord de cette côte. Or nous connaissons les venues volcaniques de la côte bétique vers Alméria et Carthagène, et ces venues sont plus jeunes que le Miocène, de même que celles du Rif. Il y a donc eu en ces régions des fractures postérieures au plissement du Rif que nous savons être lui-même postérieur au Vindobonien. Les venues volcaniques de Melilla, celles du Guelız et du Medlam, celles d'Oudjda appartiennent au Miocène supérieur, ou sont plus jeunes que lui. Les coulées et les volcans du Moyen Atlas, notamment vers Tigrigra et le Larais sont de même époque et marquent une fracture qui s'aligne à peu près sur l'extrémité occidentale de l'avancée des plis rifains. Au contraire, l'intérieur du Rif ne montre rien de volcanique. Ainsi, entre le Rif et l'Atlas se montre une région tabulaire fracturée, avec

venues volcaniques postérieures à la mise en place des plis rifains, qui sont encore bordés vers la mer par des expressions de volcanisme dans des conditions analogues à ce qui se montre pour la Cordillère bétique.

De ces différents faits, nous tirerons une premiére série de conclusions.

Le Rif apparait comme *entièrement distinct de l'Atlas et ne saurait être rattaché à l'ensemble Apennin* auquel appartient ce dernier.

Ses plissements, dirigés vers le N dans sa partie orientale vont se perdre en mer, et comme nous ne retrouvons rien au delà qui puisse se raccorder à eux, comme d'autre part, ils s'étalent vers le cap Quilatès, il est permis de penser qu'ils meurent à peu de distance de la côte.

Au contraire, dans la partie occidentale du Rif, ils franchissent le détroit de Gibraltar et s'unissent entre Gibraltar et Tarifa aux plis bétiques de l'autre rive.

Le Rif apparait donc comme une branche, (réfléchie vers le Sud et le continent africain), de la Cordillère bétique.

La forme des ses plissements ne comporte nullement la présence d'une carapace comme le pense Mr. Staub, les plis sont en effet *déversées avec régularité vers l'extérieur* de la courbe décrite par eux dans la Cordillère bétique, Gibraltar et le Rif.

Nous référant donc à des faits anciennement connus et que je n'ai pas jugé utile de reprendre, nous dirons donc que la Meseta marocaine, sur quoi se déversent les plis rifains dans l'Ouest, semble se prolonger (comme Mr. Daguin et moi-même l'avons dit), vers le Nord-Ouest. Diverses observations faites depuis, m'ont confirmé dans cette façon de voir et seront exposées ailleurs. Il en demeure que la chaine bétique, lors de la poussée relative de l'Afrique contre l'Europe, qui a provoqué la surrexion de la chaine alpine a rencontré en cette Meseta un obstacle intermédiaire sur quoi elle a été obligée de se replier partiellement comme le montrent les croquis qu'on verra plus loin. La chaine ne s'en poursuit pas moins vers l'Ouest et l'Atlantique, mais un certain faisceau de plis vient se rebrousser sur le bord NE de la Meseta.

On remarquera que dans la partie orientale du Rif, les plis, comme je l'ai déjà indiqué ([1]), ne se rattachent pas aux plis rifains proprement dits: ce sont des plis de couverture sur le pays tabulaire.

Ainsi la Meseta doit être tenus pour se prolongeant sous le Rif jusque vers Melilla et le Guiliz; elle apparait comme un des compartiments rigides qui formaient les zônes effondrées de la Méditerranée; la plupart de ceux-ci se sont enfoncés sous les flots, la Meseta marocaine a subsisté.

Nous passons maintenant à un nouvel ordre d'observations, celles relatives à l'Atlas.

Je ne reprendrai pas ce qui a été dit sur les plis qui parcourent les Hauts Plateaux ([11], [12], [13], [14]), et me contenterai de noter que la dépression

d'Azilal qui sépare le Moyen Atlas du Haut Atlas ([15]) se continue par le Haut Oued el Abid et la Moulouya supérieure pour venir se réunir à l'extrémité occidentale des Hauts Plateaux. Nous avons ainsi une zône tabulaire continue de la Tunisie à l'Atlantique, séparant les deux groupes principaux du plissement apennin dans l'Afrique du Nord:—Atlas Tellien et Saharien, et laissant cheminer à sa surface les chainons de couverture qui les unissent plus ou moins directement l'un à l'autre ([16]).

On voit dès lors que l'anticlinal de Tigrigra ([17]) dans le Moyen Atlas, et les Djebilet, tout à l'Ouest du Maroc sont les expressions en ce pays de la bordure du Moyen Atlas ([18]). Mais celui-ci arrive, vers Touahar et Taza a être coincé par les plis rifains, et ce n'est que plus à l'Est, après ennoyage sous la Moulouya inférieure qu'il reparait dans les Beni Snassen, et les collines du Nord d'Oudjda. Les Beni Snassen vont se perdre en Méditerranée, mais les collines d' Oudjda se continuent en Oranie. Or les Beni Snassen sont accompagnés de massifs anciens comme celui de Touahar et peut être une partie de celui de Tendri-Masgout. On retrouve des massifs anciens sur la côte algérienne d'Alger à Bône, dans des positions qui ne paraissent pas interdire un raccordement hypothétique des uns aux autres.

Je pense donc qu'on peut envisager la constitution de l'Afrique du Nord comme *se rattachant au système apennin et dinarique dans sa région atlasienne, au système alpin dans sa portion rifaine, aux môles rigides de la Méditerranée dans la Meseta marocaine. Dans l'ensemble ces zônes sont parallèles entre elles et cheminent de l'Est vers l'Ouest*, de la Méditerranée vers l'Atlantique, comme l'ont indiqué Mr. Staub et Mr. Argand et comme l'a fait voir plus à l'Est, pour la Corse et la Sardaigne, Mr. Termier. ([5])

Les détails ressortiront mieux de l'examen des croquis que de longues explications.

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CROQUIS DE L'AFRIQUE DU NORD MONTRANT LES RAPPORTS DE LA CORDILLERE BETIQUE. DE L'ATLAS ET DU RIF.

Légende:

I Au Nord, Meseta iberique; au Sud, Môle Saharien.

II Portions de la Cordillère bétique éloignées de Gibraltar.

III Zône tellienne (Plis apennins septentrionaux, Djebilet, Moyen Atlas en bordure de la Meseta marocaine, Monts d'Ouejda, Atlas tellien, etc.)

IV Portions supposées de l'Atlas tellien sous la mer.

V Zônes en bordure de la zône III offrant des massifs anciens.

VI Atlas Saharien et ses annexes.

VII Plis bétiques et Rifains dans la région de Gibraltar.

VIII Régions où le Trias plastique substratum des plis couchés est abondant. au voisinage de la zône VII.

IX Plis de couverture du Rif oriental sur la Meseta marocaine.

X Zône des bourrelets prérifains.

XI Hauts Plateaux et chaines de jonction entre le Sud et le Nord, l'Atlas saharien et l'Atlas tellien. (Moyen Atlas central et septentrional, chaines des Amour et des Oulad Naïl, Aurès, etc.)

XII Massifs éruptifs.

XIII Plis supposés sous marins en bordure du Rif.

XIV Cheminement hypothétique sous la mer de la zône V (Massifs anciens). et de la zône II.

XV Bordure tertiaire du Sud de la région bétique.

XVII Sens de déversement des plis.

XVIII Zône des môles effondrés et Meseta marocaine.

COUPES FIGURANT LES POSITIONS RELATIVES DES GROUPES DE PLIS ET DES FRACTURES DANS LA REGION BETICO-RIFAINE.

I Coupe N-S passant par la zône bético rifaine après la surrexion des plis du Tell et de l'Atlas.

II Coupe dans la même région après la surrexion des plis externes de la Cordillère bétique.

III Coupe dans la même région après formation des plis internes de la Cordillère bétique.

IV Coupe dans la même région après formation des plis du Rif.

V Coupe de la même région après formation de la faille du Guadalquivir, et des fractures diverses avec venues volcaniques accompagnant l'effondrement de la Méditerranée occidentale.

VI Coupe faite plus à l'Ouest, un peu au large de Gibraltar, en Atlantique à la même époque que IV.

VII Coupe faite dans la même région que VI, après effondrement de la partie septentrionale de la Meseta marocaine au large de la côte actuelle du Maroc.

ANALYSE.

I On voit la masse eurasiatique poussée devant soi par le Bouclier saharien qui en même temps la soulève et la fracture. Les Dinarides méridionales, représentées par la chaine apennine du Tell et l'Atlas sont déjà formées. Elles sont nées dès la prise de contact des deux masses continentales

II La fracture amorcée en I s'est achevée, le lambeau triangulaire ainsi détaché a été porté vers le haut et vers le Nord. Il a plissé dans ce sens les sédiments qu'il supporte; les plis externes de la Cordillère bétique se sont formés, mais sous la poussée vers le haut et vers le Nord qui continue, une nouvelle fracture s'amorce.

III La fracture amorcée en II s'est achevée, le lambeau libéré a subi le même déplacement que lambeau libéré par la fracture du I, et les plis internes de la Cordillère bétique se forment. Mais en outre, la pointe très amincie du môle saharien se fracture sous la poussée même de ce môle et la contre pression exercée par les fragments empilés d'Eurasie L'Afrique tend a passer non plus sous l'Europe, mais au dessus d'elle.

IV Sous la pression des fragments empilés et de la pousée qui continue à venir du Sud, des fractures multiples s'amorcent dans les deux masses continentales, au voisinage des surface d'appui, et les plis internes de la Cordillère, gênés dans leur développement vers l'Ouest par le bord relevé dans cette direction du fragment numéroté 1, s'incurvent et donnent par cette giration les plis rifains, numérotés 4.

V Les fractures amorcées en IV donnent naissance à des failles avec rejet plus ou moins important et à des venues volcaniques. On voit (1) la faille du Guadalquivir, (2) les volcans d'Almeria et Carthagène, (3) celui de la pointe des pêcheurs au Sud et celui d'Alboran au Nord, (4) ceux dú Guiliz et d'Oudjda, et (5) les failles du Sud d'Oudjda.

VI On voit à l'Ouest de Gibraltar les fragments 1 et 3 subsister seuls, car les fragments qui sont intervenus dans la formation des plis internes de la Cordillere betique et du Rif ne dépassent pas le détroit, la bordure relevée vers l'Ouest de 1 et 3 les fait terminer en bise au dans cette direction.

VII On voit la situation au large de la côte marocaine avec l'effondrement de toute la partie centrale mais persistance de la Meseta marocaine et de l'Algarve bordant au Sud et au Nord le fossé atlantique.

DIAGRAMMES FIGURANT LES POSTIONS RELATIVES DES GROUPES DE PLIS ET DES FRACTURES DANS LA REGION BETICO-RIFAINE.

1 Diagramme du mouvement de formation des plis externes de la Cordillère bétique et de la zône tellienne.
2 Diagramme de la formation des plis internes de la Codillère bétique.
3 Diagramme montrant la superposition des plis dans l'Est du Rif.
4 Diagramme montrant la superposition des plis dans l'ouest du Rif.
5 Diagramme des plis et des effondrements dans la région voisine de Gibraltar.

54. STUDI GEOLOGICI INERENTI ALLA COSTRUZIONE DELLA GRANDE GALLERIA ATTRAVERSO L'APPENNINO TOSCO — BOLOGNESE PER LA LINEA DIRETTISIMA BOLOGNA — FIRENZE.

PER

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La catena dell'Appennino settentrionale, a guisa di potente barriera, con cime tra i 1000 ed i 2000 m. e valichi stradali tra gli 800 e i 1300 m., divide la fertile pianura Padana dalle popolose contrade dell'Italia Centrale. Attraverso questa barriera abbiamo, nella zona Emiliana, due sole linee a semplice binario, e ad alti valichila Bologna-Pistoia, e la Faenza-Firenze, con carattgristiche che le rendono non più adatte ad un traffico intenso.

Sentita da molti anni la necessità di una nuova linea di base atta a soddisfare le crescenti e prevedibili esigenze del traffico ferroviario, nel luglio 1908 venne approvata dal Parlamento la legge per la costruzione della Direttissima Bologna-Firenze che, rappresentando un altissimo interesse nazionale, sotto il triplice punto di vista politico, economico e militare, doveva essere fatta con criteri moderni e larghezze di vedute.

La natura infida dei terreni, che costituiscono gran parte dell'Appennino Tosco-Bolognese, mostrò subito la necessità di accompagnare lo studio del progetto con accurate indagini geologiche che furono affidate al Reparto "Studi dei Terreni" dell'Istituto Sperimentale delle FF.SS. Sono ben note le difficoltà che presenta la interpretazione geologica e tettonica dell'-Appennino settentrionale, talchè ancora oggi sono vive la discussioni in proposito tra gli scienziati.

Di particolare importanza, agli effetti costruttivi, era il riconoscere l'andamento e lo sviluppo della formazione nota col nome di "argille scagliose," che presenta caratteristiche di franosità in superficie, e che da luogo a gravissime difficoltà negli scavi in sotterraneo per la tendenza al rigonfiamento con sviluppo di enormi pressioni, come si era constatato con la dura esperienza fatta nella costruzione di altre linee ferroviarie a semplice binario in terreni consimili.

E poichè le caratteristiche prestabilite pel tracciato d'una linea di base esigevano la costruzione di un lunghissimo sotterraneo di valico, occorreva scegliere un tracciato nel quale la lunghezza di attraversamento di questi difficili terreni fosse ridotta al minimo, ed era indispensabile conoscere preventivamente la natura e la successione dei terreni allo scopo di prevedere, in relazione alle medesime, l'entità dei lavori da compiere, e predisporre le modalità e la potenzialità dei cantieri e delle installazioni meccaniche principali necessarie alla loro esecuzione ed infine addivenire ad una valutazione preventiva, la più attendibile, del costo complessivo dei lavori.

Tale problema veniva aggravato dal fatto che esisteva una profonda divergenza di vedute tra i geologi italiani sulla età geologica e sui rapporti tettonici tra le formazioni arenacee costituenti in superficie il nucleo centrale dell'appennino Tosco-Bolognese e le argille. Secondo gli uni dette formazioni arenacee devono attribuirsi all'eocene inferiore e le argille scagliose all'eocene medio: secondo gli altri queste ultime apparterrebbero al cretaceo superiore e dovevano quindi intendersi come stratigraficamente sottostanti alle arenarie. E' ovvio che, a seconda delle due interpretazioni, ne derivava una profonda differenza nella lunghezza di terreno pericoloso che si sarebbe dovuto attraversare col grande sotterraneo transappenninico.

Questa divergenza di vedute dette luogo a vivaci discussioni scientifiche sostenute anche in pubblicazioni sulle riviste tecniche: e porse il destro ad aspre polemiche sui giornali quotidiani a sostegno di interessi locali.

I tecnici dell'Amministrazione Ferroviaria, in base al dettagliato studio della regione, erano giunti alla convinzione che la formazione argillosa doveva considerarsi sovrapposta a quella arenacea: ma ritennero doveroso, data l'importanza dell'opera da costruire e la necessità di predisporre degli esatti preventivi, di fare eseguire una serie di sondaggi geologici da spingersi fino oltre al piano del sotterraneo, sondaggi che confermarono pienamente quella interpretazione.

Vennero pertanto eseguite No. 7 trivellazioni a profondità variabili da un minimo di m. 135 ad un massimo di m. 386 con macchine di due tipi distinti: uno a percussione per sondaggi da eseguirsi in terreni di natura meno consistente, e l'altro rotazione, da impiegarsi in terreni più duri e compatti, capace di permettere la estrazione di testimoni. Inoltre per far fronte a qualunque evenienza, l'apparecchio a percussione venne in seguito dotato delle parti essenziali che dovevano permettere la sua rapida trasformazione a rotazione. Fra i tipi di apparecchi a percussione venne prescelto il Fauk di Vienna; per la rotazione fu prescelto il Tipo Davis-Calyx a tagliatori di acciaio con graniglia di acciaio.

Complessivamente vennero eseguiti m. 2268 di foro con un avanzamento medio giornaliero di m. 3.57 per ogni sondaggio, che escludendo le feste e le interruzioni, sale a m. 5.50. Il costo di esecuzione, compreso il trasporto dei macchinari, l'energia, l'acqua, la manutenzione ed il consumo degli impianti, fu di Lire oro 60 per metro lineare.

Grazie agli studi così compiuti, i geologi dell'Amministrazione Ferroviaria hanno potuto addivenire alla costruzione di un profilo geologico per il sotterraneo, che nel progetto definitivo aveva la lunghezza di m. 18510, di poco inferiore a quella della più lunga galleria transalpina.

I criteri adottati nella scelta del tracciato della grande galleria, oltre che geologici allo scopo di ridurre al minimo l'estensione della perforazione del terreno a facies essenzialmente scisto-argillosa, seguirono anche una razionale norma topografica sia nei riguardi dell'ossatura montana della catena appenninica, costituita da una dolce anticlinale di arenarie fondamentali, sia nei riguardi del lungo e più infido contrafforte del versante settentrionale tra le Valli del Setta e del Brasimone.

La direzione generale del sotterraneo è all'incirca Nord-Sud piegando verso oriente per soli 0° circa: grazie a tale direzione il tracciato segue l'andamento del crinale del contrafforte Setta-Brasimone per poi sottopassare il crinale appenninico, con direzione pressochè normale a quella dello spartiacque.

Nei riguardi stratigrafici questo andamento del sotterraneo è molto favorevole, perchè permette di tagliare la stratificazione per lo più a traversobanco, ma lo è ancora più riguardo alla condizione franosa dei versanti del contrafforte Setta-Brasimone, che è essenzialmente costituito da scisti-argillosi passanti in superficie alle accennate argille scagliose. Questa formazione, purtroppo tanto sviluppata nell'appennino, talchè ha reso l'Italia la terra classica delle frane, deve la sua origine alle potenti azioni meccaniche subite durante i movimenti orogenetici, che diedero origine alla catena appenninica. Una grossa pila di strati argillosi, con poche intercalazioni di strati di calcare (alberese) e più raramente di arenarie, si trovò compressa tra le arenarie fondamentali dell'eocene inferiore ed altre arenarie, se pur meno potenti, ma sufficientemente compatte, del terziario superiore. Le spinte orogenetiche, procedenti dalle arenarie inferiori a quelle superiori, schiacciarono le argille, come una massa plastica compressa tra due mascelle di non uniforme resistenza, contorcendo e frantumando gli strati di arenarie e di calcare in esse compresi, facendo assumere alle argille una struttura foglietta e scagliosa, dando ad esse movimenti incomposti e svariati a seconda del mutare delle pressioni, così da assumere talora una struttura fluidale, e spingendole ad intrudersi nelle fratture delle roccie vicine, così da simulare le forme di giaciture tipiche delle roccie eruttive.

Ad aumentare il disordine di queste roccie contribuirono anche le eruzioni di masse ofiolitiche (gabbri, diabasi, serpentini), che si insinuarono sulla formazione argillosa.

E' da notarsi che in questi terreni sovente si constatarono emanazioni di idrocarburi gassosi: e non si poteva escludere la possibilità di trovarvi degli idrocarburi liquidi, dato che i noti giacimenti di petrolio leggero dell'Appennino Emiliano sono contenuti appunto nella formazione delle argille scagliose.

Si comprende come questa tormentatissima formazione dia facilmente luogo a fenomeni franosi: l'accennato crinale tra Setta e Brasimone è tutto un succedersi di frane che or l'una or l'altra riprendono il loro movimento, talche il fondo valle, pur con versanti a dolce pendio, ha un andamento tortuoso e può considerarsi come una integrazione di frane.

Ma per quanto siano estese e profonde queste plaghe franose, esse geologicamente costituiscono pur sempre un fenomeno di alterazione superficiale; per cui non possono interessare il nostro sotterraneo, data la sua profondità e la sua distanza dai talweg laterali, grazie all'anzidetto suo andamento in rapporto alla configurazione topografica del contrafforte.

Per lo stesso motivo esso incontra i vari terreni in condizioni da non essere stati alterati nè dagli agenti esterni, nè da movimenti attuali, onde essi sono relativamente compatti anche quando sono essenzialmente argillo-scistosi, fintantochè non si verifichino filtrazioni d'acqua, nel qual caso rigonfiano con grande rapidità, sviluppando pressioni enormi. Ad ogni modo sono sempre necessari speciali accorgimenti costruttivi onde far sentire per il più breve tempo possibile l'azione dell'atmosfera umida e calda caratteristica dei cantieri di lavoro in galleria.

Dal coordinamento stratigrafico delle osservazioni compiute sugli affioramenti e sui saggi avuti dai sette scandagli eseguiti lungo il tracciato del sotterraneo ,risultó che i terreni da attraversarsi appartengono al terziario inferiore e presentano la seguente successione dall'alto al basso con relativi caratteri litologici e proprietà costruttive:

Serie Dei Terreni.

Interessati Dalla Grande Galleria dell'Appennino.

1a) strati e banchi di arenarie con interposizioni di schisti argillosi. (Vedi Fig. 1.) 1b) Calcari marnosi bianchi compati, alberese tipico con interposizioni di schisti argillosi.	Passaggi laterali dal termine 1a al termine 1 b. Quando nel termine 1a prendono sviluppo notevole le interposizioni schisto-argillose, i terreni che ne sono costituiti perdono sensibilmente la coesione e nella loro perforazione richiedono cure speciali per il loro sostegno e per un sollecito e conveniente rivestimento. Analogamente si dica pel terreno 1b) il quale viceversa assume un certo grado di compattezza quando vi predomina il calcare alberese.
2a) Schisti argillosi con passaggi ad argille scagliose. Eventuali interposizioni di schisti arenacei e marnosi: frammenti di strati di alberese e di arenaria. Roccie ofiolitiche. (Vedi Fig. 2.)	Il terreno 2a) è quello nel quale si potranno verificare le maggiori spinte, donde la necessità di solleciti ed opportuni rivestimenti. Ai suoi affioramenti corrisponde la condizione franosa dei versanti delle valli del Setta e del Brasimone. Emanazione di gas.

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Fig. 1.

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Fig. 2.

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2b) Schisti arenacei, arenarie e marne con alternanze di schisti argillosi generalmente induriti e calcari marnosi a struttura gallestrina.	Le stratificazioni 2b) costituenti in generale un terreno resistente, segnano un passaggio alla sottostante stratificazione 3) di cui condividono in complesso i caratteri costitutivi, specialmente avvicinandosi ad essa.
3) Formazione arenacea (costituita da potenti banchi di arenaria (macigno) e marne arenacee con alternanze di schisti argillosi induriti (Vedi fig. 3.)	Questo è il terreno fondamentale della catena appenninica per la zona interessata dal sotterraneo: esso è generalmente compatto, quantunque possa presentarsi più o meno fratturato. Circolazioni d'acqua.

Quanto alla previsione dell'estensione delle masse dei singoli terreni, che verebbero incontrate dall'imbocco Nord (Val di Setta) all'imbocco Sud (Val Bisenzio), nel rapporto presentato in data febbraio 1913, esse furono indicate come nello specchietto seguente, con l'avvertenza che tali estensioni dovevano intendersi con una certa approssimazione, sufficiente però per fissare i criteri di massima circa la esecuzione dei vari lavori per la costruzione del sotterraneo e per preparare un serio preventivo di costo.

Qualora si consideri che il costo previsto per la galleria per metro lineare varia da lire oro 2500 a L.8000,—a seconda della natura del terreno, si comprende facilmente tutta l'importanza della studio compiuto.

	Estensioni approssinative in cifre tonde.	NATURA DEI TERRENI CHE SI ATTRAVERSERANNO.
I	oltre 2 Km.	Strati e banchi di arenarie con interposizioni di schisti argillosi (terreno 1a)
II	circa 4.5 Km.	Zona essenzialmente di schisti argillosi con interposizioni di schisti arenacei ed anche marnosi. Gli schisti argillosi possono presentare passaggi ad argille scagliose (terreno 2a) ed eventuali incontri di roccie ofiolitiche.
III	circa 1 Km.	Alternanze di strati arenacei e schisti argillosi generalmente induriti. Possono verificarsi intercalazioni di banchi più o meno marnosi, (terreno 2b zona di passaggio al
IV	circa 8 Km.	Banchi di arenarie "macigno" e "marne arenacee" con qualche intercalazione di calcari marnosi e alternanza di schisti argillosi induriti; tipo del terreno 2b) specialmente per l'ultimo mezzo Km. verso Sud (terreno fondamentale 3.)
V	Oltre 3 Km.	Alternanza di strati e banchi di arenarie e banchi di galestri calcarei, arenacei marnosi e talora argillosi (terreno 2b.)

I lavori per la grande galleria, come pure per vari tratti della linea, vennero iniziati nell'anno 1913, ma ben presto vennero ridotti per lo scoppio della guerra mondiale e rimasero per vari anni pressochè sospesi. Nell'immediato dopo guerra le turbolenti agitazioni operaie e le difficoltè finanziarie, conseguenze dell'immane conflitto, impedirono una regolare e proficua ripresa dei lavori, che vennero condotti stentatamente, ed in condizioni anormali ed incerte.

Soltanto nel 1923, Anno I della Rivoluzione Fascista, il Governo Nazionale ha approvata la prosecuzione dei lavori ed ha provveduto i mezzi necessari dopo aver riconosciuto la necessità e la urgenza di un'opera, che abbassando di oltre 300 m. l'altezza del valico appenninico e riducendo in conseguenza le attuali lunghezze di percorso virtuale della esistente linea Porrettana di circa Km. 112 nel senso da Bologna a Firenze, e di circa Km. 78 nel senso da Firenze a Bologna, è destinata ad apportare, oltre a grandi vantaggi economici, anche una maggiore semplicità di esercizio in una parte tanto delicata e sensibile del nostro sistema fondamentale ferroviario. Si può dire che per quanto riguarda la galleria di base, è questa l'opera ferroviaria di maggiore importanza che attualmente trovasi in costruzione nel mondo. Il costo complessivo di tutta la nuova linea si aggira intorno al miliardo di Lire Italiane, corrispondenti abbastanza bene ai 200 milioni di lire oro preventivate nel 1910.

Riorganizzati i Cantieri provvedendoli di tutti gli impianti che erano stati previsti per i trasporti e per la ventilazione, spinta la esecuzione dell'attacco intermedio a mezzo di due pozzi inclinati della profondità di m. 275, i lavori presero un ritmo regolare, raggiungendo l'impiego giornaliero di circa 3500 operaie di quella mano d'opera specializzata, intelligente, sobria, disciplinata, che ha reso ricercato in tutto il mondo l'operaio italiano per lavori del genere.

L'avanzamento medio giornaliero del cunicolo inferiore variò da 2 a 4 metri per ciascuno dei 6 Cantieri agli imbocchi estremi ed agli attacchi intermedi: l'avanzamento medio complessivo fu di m.7 con un massimo di m.15,50. Il giorno 4 Dicembre dello scorso anno (1929) venne interamente forata la galleria.

Le previsioni contenute nella relazione geologica in data febbraio 1913 con allegato profilo, pubblicato secondo i disegni originali nel N° 6 del Vol. XXV della rivista Tecnica delle Ferrovie Italiane, (14 Luglio 1924) hanno corrisposto al vero, cosicchè se per gli studi geologici compiuti per la galleria del Sempione fu possibile dire che essi costituirono una "debacle" della geologia, in questo caso si è ottenuto invece un risultato veramente lusinghiero, anche perchè si è portato un efficace contributo scientifico con la sicura conoscenza della struttura appenninica, risolvendo quei dubbi geologici e tettonici che per tanto tempo avevano lasciati perplessi molti scienziati italiani. (Vedi tavola col confronto tra profilo previsto e quello controllato).

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Fig. 3

Praticamente le esatte previsioni hanno portato il grande vantaggio di mantenere il costo della grandiosa opera nei limiti del preventivo, tenuto conto, come si è detto, della svalutazione della moneta rispetto all'oro.

Partendo dall'imbocco Nord, si incontrarono alternanze di arenarie e schisti argillosi interposti (terreno 1a) ora in regolare stratificazione, ora irregolarmente disposti in seguito a forti azioni meccaniche subite che diedero luogo a fratturazioni dei banchi di arenaria e ad intrusioni dello schisto tra i banchi medesimi, come si trattasse di una massa plastica.

Quantunque le stratificazioni fossero sovente tormentate si è potuto quasi sempre distinguere un motivo dominante di pendenza verso Nord.

Ben presto incominciarono a verificarsi venute di gas, in predominio metano, specialmente dove predominava l'elemento argilloso che aveva potuto chiudere il gas come un liquido entro sacche ermetiche che conservavano una certa pressione.

Malgrado tutte le precauzioni usate di eliminazione di lampade a fiamma libera, adottando lampade portatili ad accumulatore della durata di 20 ore di accensione, avvisatori del gas, accenditori automatici a distanza, aspiratori potenti, si ebbero a verificare in questo primo tratto e specialmente in quello successivo ad argille scagliose, come era inevitabile in simili condizioni di cose e come era previsto, diversi scoppi che causarono gravi danni alle persone ed alle cose.

Le filtrazioni d'acqua si mantennero sempre in quantità limitatissima.

Alla progressiva 2300 m. si verificò il passaggio alla sottostante formazione degli schisti argillosi passanti ad argille scagliose (terreno 2a) e cioè con una differenza inferiore ad un centinaio di metri di quanto era previsto nel profilo geologico. Il piano di separazione si presentò inclinato verso Bologna di circa 15°.

La roccia si presentò subito con la tipica struttura scagliosa, a superfici lucenti con trovanti più o meno frequenti di calcare, meno frequenti di arenaria, costituiti da frammenti di strati spezzati e sconvolti e così intimamente inglobati nella massa argillosa che essa, per le enormi pressioni subite, rimaneva tanto aderente ai blocchi estratti, da costituire come una patina lucente rivelando solo ai colpi di mazza il bianco cereo del calcare alberese o la struttura granulare della arenaria.

Furono continue le emanazioni di gas e particolarmente abbondanti dove si incontrarono pile isolate di strati calcarei sempre più o meno fratturati, quasichè questi strati costituissero il recipiente, reso ermetico dalla circostante argilla, che conteneva il gas compresso.

Subito si notarono i rigonfiamenti dell'argilla, specie nel cunicolo di avanzata, a stento contenuti da potenti armature di legname costruite con sagome speciali e da centine in ferro, talchè per facilitare l'avanzata si dovette ricorrere alla costruzione a sagoma circolare del diametro di metri 3.15 con una speciale armatura a cunei di legno sostituiti poi da cunei di calcestruzzo in seguito all'incendio di una forte venuta di gas che bruciò per tre mesi.

Allo scopo di ridurre per quanto possibile l'effetto dei rigonfiamenti, si dovette rendere minimo il tempo di esposizione della roccia all'aria del cantiere, facendo seguire i rivestimenti agli scavi con la maggiore possibile rapidità, tenuto conto della grande sezione richiesta dalla sagoma circolare e degli spessori di muratura che talvolta dovettero superare un metro, come del resto era previsto.

Si studiò anche la convenienza di applicare il metodo dello scavo con lo scudo metallico a propulsione meccanica con rivestimento in ghisa ed in muratura, ma tenuto conto che le difficoltà reali presentate dai terreni non esigevano ancora questi sistemi costosissimi si soprassedette a tale applicazione che, in seguito alla migliorata natura dei terreni, non fu più necessaria.

L'attacco intermedio della Galleria a mezzo dei due pozzi inclinati ha dato luogo, durante lo scavo dei pozzi medesimi, a qualche preoccupazione, perchè si ebbe un predominio di scisti argillosi fortemente sconvolti che produssero notevoli pressioni e fecero temere di essere caduti nella formazione ad argille scagliose. Si trattava invece del terreno 2b) di passaggio alla sottostante formazione delle arenarie fondamentali. Questo terreno è costituito, come si è detto, da alternanze di arenarie e di scisti argillosi, e poichè i pozzi inclinati hanno colpito casualmente i banchi argillosi secondo la loro direzione, si è avuto un predominio di questa roccia che per le forti compressioni subite aveva assunto un certo grado di scagliosità.

E' qui il caso di ricordare che la scagliosità è una struttura consequente ad azioni meccaniche e perciò essa può riscontrarsi in terreni di epoche diverse, mentre le tipiche "argille scagliose" costituiscono un orizzonte geologico ben definito, con le loro caratteristiche proprietà che sono inerenti, non solo alla struttura scagliosa, ma anche alla composizione chimica.

E' facile ad esempio constatare che nelle tipiche argille scagliose è quanto mai scarso l'elemento calcareo, mentre negli schisti argillosi che fecero parte delle formazioni 1a) e 2b) esso è molto abbondante, costituendo sovente delle vene spatiche.

Inoltre, mentre le argille della formazione 2a) rigonfiano se trattate all'autoclave, ciò non si verifica affatto negli schisti accennati.

Pertanto i geologi dell'Amministrazione, esaminando i terreni incontrati nello scavo dei pozzi, esclusero immediatamente che potesse trattarsi delle tipiche argille scagliose: ed infatti col procedere degli scavi cominciarono ad apparire e quindi predominare le arenarie e le marne del terreno fondamentale 3) confermando pienamente le previsioni contenute nel profilo geologico della galleria dal quale il profilo dei pozzi doveva scostarsi alquanto data la loro inclinazione.

Alla base dei pozzi era prevista la costruzione di una stazione di precedenza dei treni che per un tratto della lunghezza di m.154 doveva avere una larghezza massima di m. 17,00 ed una altezza dal piano del ferro di m.0,17: tale stazione doveva anche permettere un migliore sviluppo dei lavori e dei trasporti

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Fig. 4.

Questo enorme scavo avrebbe presentato delle difficoltà forse insormontabili se avesse dovuto essere eseguito nel terreno 2a), invece si ebbe un predominio di arenaria e di schisti argillosi non rigonfianti: ciò dimostra che la zona per l'attacco intermedio dei pozzi venne scelta nel modo più opportuno.

E se pure le stratificazioni si presentarono fortemente contorte e frantumate per essere stata questa zona, vicina al nucleo centrale appenninico, particolarmente soggetta all'azione delle forze che determinarono il sollevamento orogenetico, non ebbero a presentarsi particolari difficoltà e la sagoma dei rivestimenti ed il loro spessore si mantennero nei limiti delle previsioni, e non si rese necessaria nessuna ricostruzione.

Il fatto di una relativa abbondanza dell'elemento argilloso ha portato anche il grande vantaggio di poter eseguire la maggior parte della scavo a sezione doppia del normale senza che si verificassero sensibili filtrazioni d'acqua.

Intanto però si disponeva un impianto di pompatura per far fronte alla possibilità prevista di venuta d'acqua. Ben presto infatti, procendendo con le avanzate verso Bologna e verso Firenze, attraverso le stratificazioni, sempre prevalentemente arenacee e marnose, incominciarono a verificarsi filtrazioni sempre crescenti che giunsero a superare ogni previsione. Si può dire che questo solo è il fenomeno che superò i limiti di quanto era stato previsto.

La circolazione delle acque nelle grandi masse arenacee è infatti ben poco conosciuta. Le arenarie sono per sè considerate come roccie permeabili solo per porosità e quindi debolmente assai, tanto meno poi quando nella stratificazione esistono alternanze di banchi di marna ed interposizioni di scisti argillosi, come è il caso della formazione fondamentale dell'appennino Tosco-Bolognese.

Però nello studio geologico preliminare si aveva avuto occasione di constatare come la tettonica della regione, rivelata specialmente nei profondi solchi vallivi, fosse notevolmente accidentata con conseguenti fratturazioni degli strati, si erano quindi previste filtrazioni di qualche entità e con carattere di diffusione più o meno regolare, non mai in vene concentrate di considerevoli portate, quali si verificano generalmente soltanto nelle formazioni calcaree. Invece si incontrarono sia nell'avanzata dei pozzi verso Bologna come in quella dell'imbocco Firenze, delle vene concentrate che raggiunsero rispettivamente la portata di circa litri 70 e litri 250 al secondo (Vedasi fig 4).

In complesso con l'impianto di pompe alla base dei pozzi, che andò mano aumentando di potenzialità si dovettero estrarre fino a 350 litri al secondo e dall'imbocco Firenze uscirono fino 600 litri al secondo.

L'esperienza compiuta in questo lavoro servirà anche da questo punto di vista, di esempio e di guida per casi del genere. La continua presenza delle filtrazioni d'acqua per tutta la parte centrale della grande galleria

dell'Appennino è sufficiente a confermare che essa non ha interessato, in tale tratto, la formazione delle argille scagliose, caratteristica delle quali è la mancanza d'acqua.

Quando infatti con l'avanzata dei pozzi verso Bologna venne raggiunto il passaggio alle argille scagliose, alla progressiva 1800 circa, cessò completamente ogni filtrazione. Il passaggio è avvenuto secondo un piano inclinato di circa 13° verso Bologna, dimostrando la regolare sovrapposizione delle argille alle stratificazioni arenaceo scistose del terreno 2b).

Pertanto il tratto complessivo scavato nel terreno più difficile previsto di circa 4500 m. è risultato di m.4600 non una differenza di circa il 2%.

E' quì opportuno notare che nel profilo geologico si era prevista la possibilità che, dato l'andamento complessivo delle diverse formazioni, si potesse verificare una apparizione del terreno 2b) nella parte mediana del tratto in argille scagliose. Tale apparizione, che avrebbe dovuto essere caratterizzata dalla presenza di marne e sopratutto di arenarie, non si è verificata e del resto essa doveva soltanto considerarsi come una eventualità eccezionalmente favorevole.

Dai pozzi inclinati verso Firenze i terreni incontrati furono sempre quelli essenzialmente arenacei, passanti a marne con interposizione di schisti argillosi talora con predominio di marne (terreno 3): solo negli ultimi chilometri verso l'imbocco Firenze si ebbe un predominio dell'elemento argilloso, sempre più o meno arenaceo con intercalazioni di calcare marnoso a struttura gallestrina. Mentre nella parte centrale del sotterraneo la formazione arenacea si mostrò fortemente tormentata e frantumata, procendendo verso Firenze si rendeva sempre più evidente una regolarità nella stratificazione con un motivo dominante di pendenza verso sud a conferma dell'andamento ad ampia anticlinale riconosciuto preventivamente nel nucleo centrale dell'appennino Tosco-Bolognese.

L'opera grandiosa che sta per essere felicemente compiuta, grazie al concorso armonico della scienza geologica e della tecnica delle costruzioni, deve a ragione considerarsi come una delle più interessanti, dal punto di vista costruttivo, che mai sieno state finora eseguite, perchè si tratta di un sotterraneo che se per lunghezza viene, come si è detto, dopo il Sempione, offre però rispetto a quello, caratteristiche assai differenti e condizioni affatto speciali, le quali hanno richiesto in complesso, una somma di lavori ben maggiori di quanto si è avuto nel citato valico alpino. Se in quest'ultimo si dovette lottare contro la durezza delle rocce da perforare, le elevate temperature, le acque calde ed altre notevoli difficoltà, non minore è stata la lotta che offrì per altri riguardi, la grande galleria di valico dell'Appennino, attraverso terreni che per la loro natura geologica e per le condizioni stratigrafiche, richiedono particolari cure ed una perfetta conoscenza e padronanza dei metodi più adatti per attraversarli, metodi che differiscono sostanzialmente da quelli adottati nei grandi trafori alpini.

I terreni di natura generalmente infida e non omogenea del nostro Appennino, a stratificazioni di potenza variabile e non rilevante, e per di più quasi sempre molto tormentate, richiedono in modo continuo armature di sostegno degli scavi, talora di eccezionale entità, e rendono poi necessaria l'adozione di adeguate grossezze per le murature non destinate ad una semplice funzione di rivestimento della superficie scavata, ma invece di vero e proprio sostegno e di possente contrasto alle spinte dei terreni attraversati che talora si manifestano anche molto tempo dopo che è terminata la costruzione del rivestimento.

Infatti per la costruzione del nostro sotterraneo la quantità complessiva di scavi ammonterà a circa 1,500.000 mc., sarà cioè notevolmete superiore a quelle di 758.000, 867.000, 780.000, 1.000.000, 1.100.000 avutesi mete superiore a quelle di 758.000, 780.000, 1.000.000, 1.100.000 avutesi rispettivamente nelle gallerie alpine del Frejus, S. Gottardo, Arlberg, Sempione (prima fase) e Loetschberg.

E' doveroso riconoscere che quest'opera, studiata e compiuta unicamente da ingegneri, maestranze operaie e capitali italiani, è una tangibile prova della rinnovellata energia fattiva della Nazione.

ABSTRACT.

GEOLOGICAL STUDIES INHERENT TO THE EXECUTION OF THE GREAT TRANSAPENINICAL TUNNEL FOR THE EXPRESS-LINE BOLOGNA-FIRENZE.

The express railroad Bologna-Florence, now very near completion, crosses the Apenines (which divide, like a barrier, the Northern from the Central Italy) with a tunnel 18.510 metres long, nearly as long as the longest tunnel under the Alps: the Simplon.

The area that constitutes the zone of the Appenines concerned in this work, belongs to the Tertiary System, and presents, to some extent, very unstable conditions in those portions where the clay element predominates; this is due to the great pressure resulting from the orogenetic movements that formed the chain of the Appenines.

In the above region the clay develops a special and scaly character, in form of discontinuities on the surface, or powerful movements of expansion, which have been noticed in the underground workings.

Consequently it was necessary to do a geological study of the region, in order to prepare a geognostical profile of it, which would afford a definite knowledge about the sections of the tunnel that were in need either of a greater thickness, or of a special shape, or of a frame.

But to establish such a profile became very difficult owing to the fact that a great difference of views existed among the Italian geologists on the interpretation of the geological and tectonical relation between the sandy formation constituting, on the surface the Central-Apeninical mass and the scaly clay; for this reason the experiences during construction were quite different from the anticipations based on geological interpretations.

Therefore a complete study of the case necessarily depended upon the results of numerous deep boreholes down to the bottom of the tunnel, so that now that the work is nearly finished we find the geological section agreeing with reality and our predictions confirmed.

55. ERUZIONI SOTTOMARINE IN SICILIA DURANTE IL GIURESE.

PER

RAMIRO FABIANI.

Prima ch'io avessi fatto conoscere le vestigia di attività vulcanica di cui dirò tra poco, erano considerate come più antiche per la Sicilia le formazioni eruttive di Capo Passero. Queste si ritengono infatti anteriori al Cretaceo superiore, ma non è possibile precisare di più.

Durante le ricerche da me fatte in Sicilia nel 1926 trovai le tracce di un piccolo centro eruttivo, mai segnalate dai geologi precedenti, presso la stazione ferroviaria di Roccapalumba lungo la valle del fiume Torto (fra Termini Imerese e Agrigento.) Queste tracce sono rappresentate da filoni e da resti di piccole colate (rocce basiche alteratissime), con accompagnamento di depositi di tufi e di brecciole (I.)

Il fatto notevole è che i tufi racchiudono numerosi avanzi di organismi marini: Crinoidi, Echinidi, Gasteropodi, Lamellibranchi, Cefalopodi e Crostacei. Predominano i Lamellibranchi.

Diedi un primo piccolo elenco di specie nel 1926; ricerche successive accrebbero il numero dei fossili. Affidai pertanto lo studio dettagliato della fauna alla Signa Dott. Carmela Ruiz, la quale ha preparato una monografia che pubblicherà quanto prima.

Dallo studio preliminare che avevo fatto dei fossili raccolti nelle prime ricerche mi era risultata la presenza delle specie seguenti: *Nerinea* aff. *N. triplicata* Voltz, *Pentacrinus crista-galli* Quenst., *Pteroperna pygmaea* Koch. e Dunk., *P. bajocensis* Grep., *Trigonia hemisphaerica* Lyc., *Cypricardia* cf. *rostrata* Sow., *Oppelia* cf. *subradiata* Sow., *Stephanoceras humphriesianum* Sow.

Ne dedussi trattarsi di Giurese medio e precisamente di Bajociano, ciò che venne confermato dallo studio compiuto poi dalla Signa Ruiz (che

(¹) FABIANI, R.—*Scoperta di un apparato eruttivo del Giurese medio in Sicilia* (con 1 fig. interc. e 1 tav.) Boll. Ass. Min. Sic. No. 9, dicembre 1926. Palermo, 1926.

portò alla determinazione di oltre trenta specie), anche se fra i Lamellibranchi figura un notevole contigente di specie batoniane (1.)

Tracce di attività vulcanica riportabili con tutta probabilità allo stesso periodo di quelle di Roccapalumba ho in seguito riscontrate in altre località della Sicilia occidentale; ma per esse il riferimento cronologico non può stabilirsi con rigore, mancando nei tufi qualsiasi avanzo fossile. Nelle stesse parti della Sicilia occidentale ove ho riscontrati gli accennati indizi di vulcanismo, ho del pari osservato evidenti prove di movimenti tettonici, indicate da potenti depositi conglomeratici poligenici, in corrispondenza alla base del Giurese superiore, movimenti che dovettero svolgersi in contemporaneità o quasi alle manifestazioni eruttive (2.)

Coi nuovi elementi da me segnalati, si può dunque concludere per lo svolgimento dei fenomeni di vulcanismo attraverso i tempi geologici in Sicilia, come segue:

L'attività vulcanica nell'area presentemente occupata dalla Sicilia ebbe sicuramente inizio nel Giurese medio con centri eruttivi sottomarini, i quali emisero lave e prodotti piroclastici. Questi ultimi si accumularono in seno alle acque, seppellendo una fauna abbastanza ricca e variata, il cui studio ha rivelato che il fenomeno ebbe luogo o almeno culminò nel Bajociano.

I dicchi e filoni di rocce basiche sparsi nella Sicilia centrale e occidentale, e che le mie ricerche (3) dimostrarono assai più numerosi di quanto risultava in precedenza, indicano che l'attività endogena in queste parti dell'Isola persistette anche in tempi successivi, soprattutto nel Terziario. Però i centri di attività vulcanica più appariscente ed imponente si vennero costituendo nella Sicilia orientale, iniziandosi all'estremità meridionale (Capo Passero, Pachino) e spostandosi durante il Terziario e il Quaternario verso il Nord, cioè rispettivamente in corrispondenza ai Monti Iblei e all'Etna.

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(1) RUIZ, C.—*La fauna dei tufi vulcanici giuresi di Roccapalumba in Sicilia.*—Rend. R. Acc. Naz. dei Lincei Vol. VIII, ser. VI, fasc. II. Roma, 1928.

(2) Per ulteriori particolari rimando alla mia Nota: *Vestigia di vulcanismo e di movimenti tettonici nel Giurese di Sicilia* (con 2 fig. int.) Boll. Soc. Geol. Ital. vol. XLVII, fasc. 2. Roma, 1929.

(3) FABIANI, R.—*Risultati delle escursioni geologiche da me fatte in Sicilia durante il 1925 e il 1926.* Boll. della Soc. di Sc. Natur. ed Econ. di Palermo Ann. VIII, Palermo, 1926. (Ristamp. con brevi aggiunte nel Boll. Ass. Min. Sic. No. 2, aprile-maggio 1927. Palermo, 1927).

ABSTRACT.

SUBMARINE ERUPTIONS IN SICILY DURING THE JURASSIC TIME

During his geological researches in Sicily and specially on the Western part of this Isle, the Author met with several remains of volcanic rocks.

The particularly interesting place for these investigations is Roccapalumba in the district of Palermo. There, the basaltic lava is extremely altered and mixed with tuffs

These tuffs contain several remains of marine organisms (as corals, brachiopods, echinoderms, molluscs) and moreover, the *Pentacrinus bajocensis* D'Orb., *Trigonia hemisphaerica* Lyc., *Oppelia subradiata* Sow., *Stephanoceras humphriesianum* Sow., are present with several other species, giving evidence that the tuffs were deposited on the Bajocian.

Therefore, the volcanic activity in Sicily began in the Jurassic.

That means, not only for Sicily, but stili for Italy, the first discovery of volcanic fossiliferous tuffs in the Jurassic.

56. ANALOGIE TETTONICHE FRA LA SICILIA E LA TUNISIA.

RAMIRO FABIANI.

Nella concezione della struttura tettonica generale della Sicilia si può dire che il campo resta ancora diviso fra quelli che concordano nell'idea dei grandi "carreggiamenti" espressa per la prima volta da Lugeon ed Argand (1) e seguita dall'Arbenz, da Limanowski, da Rovereto e da altri e quelli (Di Stefano, Scalia, M. Gemmellaro ed altri) che tale interpretazione non ritengono giustificata.

Non è qui il luogo di entrare in particolari, riportando le ragioni e gli elementi di dettaglio invocati dagli uni e dagli altri a sostegno della rispettiva opinione. Riferendomi specialmente alla Sicilia media e occidentale, ricorderò solo che ai primi si era mosso in sostanza l'appunto di essersi eccessivamente appoggiati a quanto poteva esser messo in evidenza dalla carta geologica della Sicilia pubblicata dal R. Ufficio Geologico.

Da questa carta infatti si potevano dedurre per numerose località tali rapporti di giacitura tra le formazioni calcaree e dolomitiche del Trias superiore e quelle dell'Eocene da giustificare, sia pure con l'appoggio di alcuni elementi di fatto, l'idea che il Trias ed altri terreni del Secondario ricoprano i depositi eocenici.

I geologi siciliani e particolarmente il Di Stefano (2) dimostrarono per varie località che quei depositi, segnati come eocenici sulla carta geologica, spettavano invece al Trias e precisamente ad orizzonti sottoposti alla serie calcarea e dolomitica di detto periodo.

Nelle numerose escursioni da me fatte durante un quadriennio in Sicilia, ho trovato diverse altre località (3) ove tale scambio di terreni, del resto comprensibile in un primo rilevamento data la somiglianza di facies, era avvenuto (e non solo fra Trias ed Eocene.)

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(1) LUGEON, M. et ARGAND E. - *Sur des grands phénomènes de charriage en Sicile.* Comptes Rendus de l'Ac. des Sciences, t. CXLII. Parigi, 1906.

(2) DI STEFANO, G. — *I pretesi grandi fenomeni di carreggiamento in Sicilia* — Rend. R. Acc. Naz. dei Lincei, XVI, I sem., ser. 5, fasc. 5-6, Roma, 1907.

(3) FABIANI, R. — *Risultati delle escursioni geologiche da me fatte in Sicilia durante il 1925 e il 1926.* Boll. Ass. Min. Sic. No. 2, aprile-maggio. Palermo, 1927.

L'accennata circostanza di contatti anormali semplicemente apparenti e molti casi in cui analoghi contatti sono invece dovuti evidentemente a faglie e a pieghe-faglie, depongono naturalmente contro l'interpretazione della struttura tettonica a grandi ricoprimenti. Non si può però generalizzare neanche in tale senso. E qui va osservato che, come in dipendenza dalla costituzione geologica, così anche dal punto di vista tettonico si può dire che esistano "due Sicilie": la Sicilia nord-orientale (Caronie e Peloritani), ove assumono notevole sviluppo scisti cristallini diversi e rocce granitiche, e il resto dell'Isola dove tali rocce non sono presenti. Ora non si può negare che nella prima parta della Sicilia abbiano sviluppo fenomeni di ricoprimento più o meno estesi, ma d'importanza tale da costituire un motivo predominante, per lo meno come struttura a scaglie (4), della tettonica della regione. Pel rimanente dell'Isola, che comprende dunque gran parte della Sicilia orientale e tutta la centrale e l'occidentale, i dati raccolti in un lungo e complesso lavoro di ricerca non mi hanno persuaso che la struttura tettonica risponda al motivo dei "grandi carreggiamenti."

Ho osservato bensì in vari punti (segnatamente nei dintorni di Palazzo Adriano, cioè nel gruppo del M. Rose, ivi compreso il bacino superiore del fiume Sosio) dei casi di ricoprimento (5), ma, per quanto notevoli e interessanti, ho tratto la convinzione ch'essi rappresentino dei fenomeni di portata locale. Lo studio delle condizioni di giacitura di alcune rupi calcaree emergenti isolate tra rocce di età molto più recente e spesso sradicate (es. rupi permiane della valle del Sosio), la posizione anormale di alcune masse di formazioni triasiche (marne e argille con intercalazioni di calcari lastriformi ad Halobie riportabili in gran parte al Carnico) ed altri particolari pei quali rimando ad altre mie pubblicazioni ([1]), mi hanno invece condotto a pensare che ad altri fenomeni che non siano quelli dei grandi ricoprimenti debba imputarsi la struttura della maggior parte della Sicilia.

Già due anni or sono esprimevo l'opinione che molte delle accennate condizioni di giacitura non potessero meglio spiegarsi se non come risultante di fenomeni di diapirismo. A due anni di distanza, pure avendo raccolti numerosi altri elementi di fatto, ritengo del pari di dover concludere che, allo stato attuale delle mie conoscenze, la tettonica della Sicilia sud-est, centrale e occidentale, appare come risultante del concorso di fenomeni di faglia, talora di notevole entità e di vario tipo (faglie inverse, anche con

([4]) Ho accennato in altre pubblicazioni a questo modo di vedere, del quale non solo mi sono persuaso per numerose osservazioni da me fatte in vari punti delle Caronie, ma in seguito pure a scambi d'idee avuti al proposito col prof .G. Dal Piaz che da parte sua raccolse molti elementi di fatto a sostegno della interpretazione sopra ammessa per la struttura tettonica della Sicilia nord-orientale.

([5]) Per dettagli a questo riguardo vedansi le mie Note: *Risultati delle escursioni geologiche da me fatte in Sicilia durante il 1925 e il 1926*; Boll. Ass. Min. Sic. No. 2, aprile-maggio 1927. Palermo, 1927 e: *A proposito d'una ricerca del Carbonifero in Sicilia.* Boll. Ass. Min. Sic. Ann. V, No. 4, Aprile 1929. Palermo, 1929.

ricoprimenti più o meno estesi) con fenomeni diapirici, i quali assumono a volte una parte di prim'ordine.

Per quanto sappia per esperienza diretta che la tettonica siciliana è complicata da numerosissimi e talora insospettati elementi di dettaglio, talchè sono ben lungi dall'illudermi d'esser giunto a conclusioni definitive, credo comunque interessante segnalare le analogie fra l'interpertazione da me indicata per la tettonica della Sicilia media e occidentale e le vedute recentissime del Termier ([1]) sulla tettonica della Tunisia, per la quale pure si era pensato un tempo ai grandi carreggiamenti. Le analogie emergono senz'altro dai seguenti passi che trascrivo dalla comunicazione qui sotto citata dell'insigne geologo francese:

"Aujourd'hui, après les études patientes et detaillées de Marcel "Solignac, ([2]) et après les observations que nous avons, cet excellent "géologue et moi, faites ensemble en 1926 et au printemps dernier, l'hypo-"thèse du charriage doit etre définitivement écartée. La Tunisie n'est en "aucune manière un *pays de nappes*." (l.c. pag. 13.)

E più sotto (pag. 15), dopo aver segnalate le curiose condizioni di giacitura del Trias (che ricordano molto quelle da me osservate in vari punti della Sicilia) e accennato alla spiegazione che di tali condizioni ne davano i geologi di Algeri in confronto con quelli di Parigi, il Termier soggiunge: "Leur explication (cioé quella data dai geologi algerini) des "anomalies était souvent insuffisante et peu vraisemblable, parce que, "comme nous tous à l'époque, ils ne connaissaient pas ou connaissaient mal "le phénomème du dôme de sel; mais ils avaient raison de considerer le "Trias comme monté de la profondeur, tandis que mon hypothèse du Trias "charrié, du Trias en *Klippes* ou en debris de nappe flottant sur un pays "autochtone et s'encastrant plus ou moins dans leur substratum de hasard, "mon hypothèse, longtemps seduisante, n'est plus défendable aujourd'hui. "De Gabès au R'arb, dans toute la vaste contrée où le Trias présente les "anomalies que j'ai rappelées, l'Afrique française du Nord est un *pays de* "*dômes de sel* et, à coup sûr, l'un des mieux caracterisés qui soient. Cela "ne veut pas dire que l'on ne puisse pas y trouver, çà et là, quelques "témoins d'un phénomène de charriage; mais le charriage, si charriage il "y a, s'avérera comme un fait local et subordonné, et non plus comme le "trait dominant de la structure."

Ora, avuto presente che anche riguardo ai casi di ricoprimento osservati nella Sicilia occidentale mi esprimevo in forma simile (v. *Risultati delle ricerche* ecc. pag. 22) ed astraendo pel momento dalle "cupole di sale" parmi dunque che non potrebbe essere più suggestiva l'analogia tra le con-

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([1]) TERMIER P.—*Recentes impressions de voyage.*—Conférence prononcée dans l'Assemblée generale de la Société Helvetique des Sciences Naturelles à Lausanne le 2 septembre 1928. Berne, 1928.

([2]) Vedi la grossa monografia del Solignac *Etude géologique de la Tunisie septentrionale*. Direct. gen. des Trav. Publ. Tunisi, 1927.

clusioni del Termier sulla tettanica tunisina e quelle mie sulla tettonica della Sicilia media e occidentale, quali ho formulate già due anni or sono e che gli studi successivi non mi hanno fino al presente smentite.

ABSTRACT.

TECTONIC ANALOGIES BETWEEN SICILY AND TUNISIA.

Lugeon and Argand were first in considering the tectonic structure of Sicily as resulting from some imposing phenomenon of thrusts.

Italian geologists however, did not accept their conception. As a matter of fact, there exists effectively, in north-eastern Sicily, at least one tectonic scale-structure. Whereas in the remaining part of Sicily the author has not succeeded, so far, in finding other elements corroborating the above interpretation.

The author believes that the tectonics of central and western Sicily result from the co-operation of phenomena of faults of great importance, and different type (reverse faults and even thrust-faults) with diapiric phenomena.

This conception now finds a surprising collation in the tectonic interpretation of Tunisia. In fact, Termier, also on the basis of the detailed studies of Marcel Solignac, concludes:

„L'hypotèse du charriage doit être définitivement écartée. La Tunisie n'est en ancune manière un *pays de nappes*............

l'Afrique française du Nord est un *pays de dômes de sel*............

Cela ne veut pas dire que l'on ne puisse pas y trouver, cà e là, quelques témoins d'un phénomène de charriage; mais le charriage, si charriage il y a, s'avérera comme un fait local et subordonné et non plus comme le trait dominant de la structure."

57. DIE GEOLOGISCHE ERFORSCHUNG DES SÜDATLANTISCHEN OZEANS DURCH DIE DEUTSCHE ATLANTISCHE EXPEDITION

VON

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Die Erforschung des Meeresboden hat nicht mit der des festen Landes Schritt halten können. Sie verlangt, dass man gewissermassen mit verbundenen Augen seine Proben aus grosser Entfernung holt, ohne durch den Angenschein die Stellen aussuchen zu können, die zur Entnahme am günstigsten erscheinen. Wir müssen uns demnach mit Zufallsproben begnügen. Allerdings liegen die Verhältnisse am Meeresboden insofern günstiger, als wir dort im allgemeinen nicht so rasch wechselnde Einflüsse wie auf dem festen Lande haben und infolgedessen mit einer grösseren Gleichartigkeit der Sedimente rechnen können. Dennoch waren die bisherigen Untersuchungen mehr Stichproben die höchstens in Reihen angeordnet waren. Um vom Zufall möglichst loszukommen, hat die Deutsche Atlantische Expedition auf dem Forschungsschiff METEOR die regionale, systematische Untersuchungsweise eingeschlagen.

Sie hat nach dem Plane von ALFRED MERZ den Atlantischen Ozean zwischen rund 20 Grad Nord und 65 Grad Süd 13 Mal gequert und systematisch erforscht, indem Ozeanographie, Biologie, Chemie, Meteorologie und Geologie bezw Mineralogie Hand in Hand gearbeitet haben. Geologie und Mineralogie haben sich planmässig so in das Gebiet geteilt, dass der Verfasser von der Antarktis bis etwa 5 Grad Süd 206 Stationen der Expedition mitgemacht hat, während Prof. CORRENS auf dem Rest der Reise an 104 Stationen mitwirkte.

Die regional-systematische Untersuchungsweise scheint mir beinahe die einzige zu sein, mit der wir die Absatzbedingungen der Sedimente und damit sie selbst wirklich erfassen können und das trifft nicht nur auf die Tiefen der Ozeane zu sondern auch bei entsprechender Dichte des Netzes auf epikontinentale Meere, wie ich in der Nordsee oder selbst in grossen Lagunen wie dem Kurischen Haff an der Ostsee beweisen konnte. Auch dort hat die regionale Arbeitsweise die jeweiligen Hauptfaktoren welche die Art des Sedimentes an dem jeweiligen Ort bedingen, aufzeigen können.

Zu der regionalen Betrachtung kommt die zahlenmässige Erfassung der Sedimente, um von den Schätzungen und allgemeinen Beschreibungen loszukommen. Die Zahlen sind aber stets unter dem Gesichtspunkt zu verwenden, dass die Sedimente keine einheitlichen Mineralien, keine chemischen Verbindungen sind und stets gewisse Schwankungen in ihrer Zusammensetzung aufweisen.

An einigen Beispielen möge die regionale Arbeitsweise mit ihren Erfolgsmöglichkeiten gezeigt werden. So zunächst am *Kalkgehalt* der Sedimente, der auch bei fossilen Absätzen von grosser Bedeutung ist. Er entsteht im Atlantischen Ozean anscheinend restlos durch Organismenreste, chemisch gefällter Kalk konnte nicht nachgewiesen werden, denn überall war das Bodenwasser nicht gesättigt, es war im Gegenteil in der Lage $Ca\ CO_3$ aufzulösen. Der Kalkgehalt stammt demnach aus den Planktonten der oberen Wasserschichten, die ihn dort aus dem Wasser entnehmen und in ihren Schalen und Skeletten anreichern. Man versuchte bisher die Verteilung des Kalkgehaltes in den Sedimenten, besonders die Verbreitung des kalkarmen roten Tiefseetones und der kalkreichen Globigerinenschlamme allein durch die Tiefen zu erklären, welche die Schalen zu durchfallen hätten. Dabei werden sie verschieden weit aufgelöst. Dieser Faktor ist sicherlich vorhanden, doch er ist nicht der wesentlichste und ausserdem ist er nicht gleichartig auf der ganzen Erde, da die Wasser verschiedene Lösungsfähigkeiten haben können. Die Verhältnisse des Südatlantischen Ozeans zeigen das ohne weiteres. Auf den Höhen der Mittelatlantischen Schwelle, des Walfischrückens und des Riogranderrückens sind, wie zu erwarten ist, die Kalkwerte am grössten und in den Tiefen der Brasilmulde und des Argentinischen Beckens am geringsten, doch es fällt hier schon auf, dass der Übergang von Kalkreichtum zu Kalkarmut so plötzlich erfolgt. Da müssen noch andere Kräfte mitwirken. Auf der afrikanischen Seite stimmt die Tiefenabhängigkeit garnicht mehr, denn in den gleichen Tiefen und Breiten wie auf der amerikanischen Seite sind hier um 60 und mehr Prozent höhere Werte, und selbst innerhalb der Kongomulde schwanken bei gleicher Tiefenlage die Werte ebenfalls.

Diese Abweichungen finden ihre Erklärung in den Ergebnissen der Ozeanographen, die feststellten, dass im Westen ein kalter antarktischer Tiefenstrom bis über den Aequator vordringt, während er im Osten in der afrikanischen Hälfte des Ozeans bereits am Walfischrücken abgesperrt wird. Wo dieser Strom am Boden fliesst haben wir geringen oder keinen Kalkgehalt, wo er fehlt, hohen. Er wirkt lösend, wie durch den hohen Alkalinitätsgehalt des Bodenwassers nachgewiesen werden konnte.

Ausserdem wirken die Ströme durch ihre verschiedenen Geschwindigkeiten, die in den höheren Lagen im allgemeinen grösser sind. Auf den Erhebungen sind sie dann imstande, die feinste tonige Substanz herauszuschlämmen und in die Tiefen mit geringerer Wasserbewegung zu führen, die damit als Sammelmulden dienen. So reichern sich die gröberen

Foraminiferenschalen auf den Rücken an und in den Tiefen die tonigeren Bestandteile und unterstreichen dadurch noch die Wirkung des Tiefenfaktors. Der rasche Übergang erhält so seine Erklärung.

Berücksichtigen wir weiter, dass der Kalkgehalt von der Menge der kalkliefernden Planktonten abhängig ist und dass deren Verbreitung mit dem Klima und den Oberflächenströmen in Beziehung steht, so ist schon in der einen Eigenschaft der Sedimente "Kalkgehalt" sehr viel von der Umwelt abgebildet, wir finden in ihm Tiefe, Strömungen nach Wasserart und Stärke, Besiedlung des Meeres in den höheren Wasserschichten und die klimatischen Verhältnisse an der Meeresoberfläche wieder.

Die anderen Eigenschaften werden ebenfalls davon beeinflusst, so die Verteilung der Korngrössenanteile, die in grösserer Entfernung von der Küste nur doch ganz untergeordnet einen kontinentalen Faktor durch Einschwemmungen oder Einwehungen vom Festland aufweisen. Wir stellten vorher bereits fest, dass die verschieden starken Strömungen das Sediment in Bezug auf seinem Kalkgehalt verändern können, indem bei grösseren Stromgeschwindigkeiten das Allerfeinste weggeführt und an anderen Stellen abgesetzt wird. Aus den Wassern des festen Landes und der Flachsee ist das eine bekannte Tatsache. Es zeigt sich nun, dass auch in den Ozeanen die Strömungen stark genug sind, um diese Wirkungen allerdings mit feineren Unterstufen hervorzurufen. Die Ströme in den höheren Teilen sind, wie bereits erwähnt, in der Regel kräftiger als in den Tiefen und so sind die Sedimente auf den Rücken meist grobkörniger durch die relative Anreicherung des schwereren, größeren Materials—meist Foraminiferenschalen—als in den Senken, wo sich das Feinste ansammelt und der gröbere Kalk häufig aufgelöst wird. Die Korngrössen sind von den Strömungen und somit vom *Relief des Meeresbodens* abhängig, eine überaus wichtige Tatsache, die sich bereits auf unserem ersten Profil zeigte. Auch hier wirkt die Planktonverteilung mit, denn wo zahlreiche Pteropoden vorkommen, werden die Sedimente besonders grobkörnig. Allerdings fallen die Aragonitschalen der Pteropoden unverhältnismässig rasch der Auflösung im Sediment anheim.

Am deutlichsten prägt sich die Verteilung der schalentragenden Kleinlebewesen und damit die Richtung der Oberflächenströme in der Verbreitung der einzelnen Spezies im Sediment aus, die nur durch regional-systematisch angelegte Stationen und systematische mikroskopische Untersuchung erfasst werden kann.

Eine weitere Untersuchung gilt der organischen Substanz im Sediment, für die ein Anhalt durch das Mass der Oxydierbarkeit mittels Kaliumpermanganat gewonnen wird. Es zeigt sich eine Zone hoher Werte quer über den Ozean in der Breite von Südafrika, die sich so ziemlich räumlich mit der Verbreitung der Konvergenzlinien der Oberflächenströme deckt und man kann sich vorstellen, dass diese vielleicht dadurch abgebildet werden, indem

an diesen Linien eine höhere Planktonsterblichkeit eintritt. Die Planktonzahlen sind für diese Zonen gegenüber den nördlicheren und südlicheren Werten besonders gering.

Besondere Ereignisse wie Staubstürme aus Wüstengebieten, Aschenregen aus Vulkanausbrüchen, untermeerische Ergüsse, Abschmelzen der mit Schutt beladenen Eisberge lassen sich aus dem mikroskopischen Bild der Sedimente herauslesen.

Die bessere Kenntniss von den Sedimentationsbedingungen wird nach Beendigung unserer Auswertungen eine Einteilung der Sedimente nach Tiefenregionen noch mehr als bisher als unzureichend erscheinen und eine Gruppierung nach anderen Gesichtspunkten etwa nach dem Kalkgehalt in Verbindung mit den organischen Resten suchen lassen.

Aus den Bildungsarten der Sedimente werden wir umgekehrt bei anderen Sedimenten auf ihre Entstehungsbedingungen schliessen können und so sind die Tiefseesedimente nicht länger wie früher bei den gelegentlichen Stichproben Ding an sich, sie werden vielmehr zum wichtigen geologischen Hilfsmittel, zur geologischen Urkunde im weitesten Masse.

Um unsere Erfahrungen ausnutzen zu können, müssen wir möglichst lange Proben haben, die recht viele Schichten umfassen. Die Expedition hat durchweg längere Proben als ältere Expeditionen erzielt und hat mit den Stossröhren bis zu 98 cm. lange Proben heraufgebracht. In flacheren Gewässern mit mehr sandigen Sedimenten sind die Stossröhren nicht in dem gleichen Masse geeignet, dort haben wir mit Greifern gearbeitet und manchmal bis zu 8 Liter Sediment gewonnen. Diese Mengen lassen auch methodische Versuche und Spezialuntersuchungen zu. Die Stossröhrenproben kommen in Glasröhren herauf und zeigen häufig Schichtung, die in einer plötzlichen völligen Änderung des Sedimentes oder in einem allmählichen Übergang bestehen kann. Die Sedimente der Kapmulde im Südwesten Afrikas sind besonders stark geschichtet und anscheinend hat sich das Relief des Meeresbodens und damit der Verlauf der Strömungen hier in der Sedimentationszeit unserer Proben geändert. So können wir in allen Gebieten aus den tieferen Teilen der geschichteten Sedimente auf die veränderten Verhältnisse in früheren Zeiten schliessen, wenn erst alle Proben ausgewertet sind.

Der Einfluss der Bodenformen auf die Sedimente und auf die Strömungen wurde wiederholt gestreift, sie spielen eben für alles, was im Ozeangefäss vor sich geht eine ausschlaggebende Rolle. Das wäre Grund genug für die Expedition gewesen, vom Meeresboden durch Echtlotungen ein möglichst genaues Bild zu gewinnen. Bisher waren in wenigen Gebieten Lotungen dicht genug, um Einzelheiten zu erkennen. Der METEOR hat aus seinem Arbeitsgebiet fast 70,000 Tiefseetiefenangaben mitgebracht, die es ermöglichen, die morphologische Karte wesentlich zu vervollständigen und selbst Einzelheiten auf den überfahrenen Strecken auszumachen. Das

Kartenbild und die Gestaltung im Einzelnen lassen Rückschlüsse auf die Natur und die Entstehung der Formen zu, besonders wenn man die Sedimente und die Geologie der Inseln und Küstenländer mit heranzieht. Wir haben somit ein Hilfsmittel an der Hand, vielleicht entscheidend in den Kampf der Meinungen um den Aufbau und um die Entstehung des Atlantischen Ozeans einzugreifen. Zwei Extreme stehen sich gegenüber, einmal die Anhänger einer mehr oder minder langen Permanenz des Ozeans wie SOERGEL, KOBER, DIENER, HAUG und andere und dann die Verschiebungstheoretiker mit WEGENER und ARGAND als Führer, die eine Westdrift annehmen. Die Beziehungen zwischen Afrika und Südamerika sind so eng, dass auch die erste Gruppe Landverbindungen, schmalere Landbrücken oder breite Zwischenkontinente annehmen muss, die später einbrachen. Einen Zwischenstandpunkt nimmt DU TOIT insofern ein, als er nur einen schmaleren Teil einbrechen und das Übrige driften lässt. Wieder eine andere Gruppe behält wohl eine Drift der Kontinenmassen bei, wie STAUB, doch die Richtung ist nur ganz untergeordnet westlich, in der Hauptsache abwechselnd polwärts und polflüchtig und so bleibt für den Atlantischen Ozean trotz der Bewegungen eine gewisse Konstanz. Aus diesen Grundanschauungen heraus werden dann die Erklärungen für die Formenelemente des Atlantischen Ozeans abgeleitet, besonders für die charakteristische Mittelatlantische Schwelle. Es ist nicht weiter verwunderlich, dass dabei die widersprechensten Deutungen herauskommen, so wird der Rücken im südatlantischen Ozean von STAUB südlich der Romanche Tiefe als eine Horstzone des versunkenen Gondwanalandes aufgefasst, auf der nördlichen Halbkugel soll er orogener Natur und Teil der mediterranen Kettengebirge sein; WEGENER sieht in ihm einen Streifen der Kontinentränder, der versunken und in der Mitte liegen geblieben ist und ANDRÉE äusserte etwas ähnliches. STILLE spricht ihm als Mittelschwelle in einer Geosynklinale epirogenetische Entstehung zu und HAUG und KOBER orogenitische, wobei sich die beiden letzteren dadurch unterscheiden, dass HAUG ein Faltengebirge im Entstehen darin sieht, während KOBER ein wieder absinkendes Orogen aus der Kreide-Tertiärzeit darin zu erkennen glaubt. Es hat eigentlich jede Möglichkeit ihren Vertreter gefunden, die bald in dem einem, bald in dem anderen Sinne von den Seismikern gestützt werden.

Glückt unsere morphologische Analyse mit genügender Sicherheit, also die Ausdeutung ob Schollengebirge oder Faltengebirge oder Vulkankette oder etwas anderes, so bedeutet das einen wesentlichen Fortschritt und unter Mitbenutzung des kartographischen Bildes also des Verlaufs wird manche Anschauung stark revidiert werden müssen. Wir werden uns bei der Analyse vor Augen halten müssen, dass unter dem Meeresspiegel entstandene Formen durch das Fehlen der Erosion und der Temperaturunterschiede aber durch das Vorhandensein starker Lösungsmöglichkeiten anders abgetragen werden als auf dem festen Lande.

Die Auswertung der grossen Zahl der Lotungen, die reduziert werden müssen, ist noch nicht beendet, das letzte Wort kann deshalb hier noch nicht gesprochen werden. Dennoch glaube ich nach dem heutigen Stande in dem mittelatlantischen Rücken ein Kettengebirge sehen zu müssen, zwar nicht im Sinne KOBERS als Teil der orogenen Ringe um die Kontinente, sondern als einen langen Nord-Südzug parallel zu den Anden bis zum Antarktischen Kontinent, der im Süden in dem atlantisch-indischen Querrücken und seiner wahrscheinlichen Fortsetzung, dem Kerguelen-Gaussbergrücken die gleichen Biegungen wie der Südantillenbogen macht. Der Südantillenbogen, an dessen Aussenseite wir die grösste Tiefe des Südatlantischen Ozeans mit 8060 m. gefunden haben, kann wohl durch die Lotungen und die ozeanographischen Befunde des METEORS als gesichert gelten, so dass die Anden in ihm zum Grahamland fortgeführt werden. Es ist weiterhin wahrscheinlich geworden, dass sich die argentinischen Patagoniden WINDHAUSENS über den Patagonischen Schelf und die Falklandsinseln bis nach Südgeorgien fortsetzen und sich dort mit dem Andenzug scharen. Zwischen beiden liegt ein grosser Block aus Grundgebirge, der in Patagonien in verschiedenen Ausbissen und auf den Falklandsinseln am Kap Meredith herauskommt. Dieser nun wieder auflebende Südantillenbogen macht den Anschauungen von STAUB, KÜHN, u.a. einen Strich durch die Rechnung und stützt die von NORDENSKIÖLD.

Die Querrücken, die z.T. neu gefunden oder in ihrer Ausdehnung erst richtig festgelegt wurden, sind verschiedenartig geformt und wohl auch gebaut. Die meisten sind von den Tektonikern garnicht berücksichtigt worden, nur KRENKEL braucht sie für seine Vergitterung des Meeresbodens, die er vom afrikanischen Festland überträgt und die manches für sich zu haben scheint. In Verbindung hiermit ist es eine bemerkenswerte Tatsache, dass die Vulkaninseln gerade an den Ansatzstellen der Querrücken an die Zentralschwelle liegen, und vielleicht als Kreuzungspunkte zweier tektonischer Richtungen aufgefasst werden können.

Auch die Frage der Tiefseegräben, im Atlantischen Ozean besser der grossen Tiefen, die neuerdings VON LEUCHS wieder angeschnitten wurde, erhält wesentliches Material durch die Meteor-Lotungen, und im Gegensatz zu LEUCHS muss gerade eine Anlagerung der Tiefen an die Rücken festgestellt werden.

Neu und besonders für Afrika von Interesse ist eine Reihe von Erhebungen, die von der Agulhasbank zur Bouvetinsel hinüberziehen. Vielleicht sind die Höhen dieser "Kapschwelle" eine Fortsetzung der nach Süden abbiegenden Kapfalten, denn es ist auffällig, dass ich von einer dieser Höhen an der Mittelatlantischen Schwelle Quarzit mit dem Lotgerät heraufgebracht habe, der dem Tafelbergsandstein durchaus ähnlich ist. Man denkt natürlich auch an Eisberge, die Material von Süden her verfrachtet haben könnten, doch auf dem tieferen Boden ringsherum lagen keine Gesteinsstückchen.

Eine ebenfalls für die Geologie von Südafrika wesentliche Feststellung konnten wir südlich der Agulhasbank machen. Dort haben wir zweimal Höhen gekreuzt, die sich um über 1.500 m. über ihre Umgebung erheben und vom Kontinenantalsockel durch Tiefen von 4.000 m. getrennt sind. Man geht wohl nicht fehl, wenn man diese beiden Erhebungen als zu einem ost-westlich gerichtetem Höhenzuge gehörig betrachtet, der parallel mit den Kapfaltengebirgen verläuft. Das wäre dann wohl ein Teil der versunkenen karbonischen Kapfalten, deren Vorhandensein von den südafrikanischen Geologen immer wieder aus den nach Norden verfrachteten Sedimenten geschlossen wurde.

Ähnliche Dinge gibt es auch an der Südamerikanischen Seite, doch der Raum reicht nicht, sie durchzusprechen.

Sie sehen jedoch den Weg, auf dem gerade die Morphologie des Ozeanbodens zu den grossen Fragen des Erdaufbaus wesentlich klärend beitragen kann. Sie wird neben der Ausdeutung der Sedimente, die durch Ozeanographie, Chemie, Biologie und Meterologie unterstützt wird, im Verein mit der Geologie der Küstenländer und Inseln jedenfalls bedeutsam in den Streit um die Geschichte des Atlantischen Ozeans eingreifen. Zum mindesten werden neue Anregungen gegeben und die neuen Erkenntnisse können auf andere Ozeane übertragen werden.

So hat die Geologie durch die Deutsche Atlantische Expedition manche Förderung erfahren und gerade durch die systematische-regionale Arbeitsweise konnten Probleme in Angriff genommen werden, bei denen die früheren Stichproben nicht als Grundlage ausreichten.

58. ÉTAT DE NOS CONNAISSANCES EN 1929 SUR LA GÉOLOGIE DE L'INDOCHINE FRANÇAISE.

PAR

F. Blondel.

Chef du Cervice Géologique de l'Indochine.

Suivant une tradition établie depuis 1913, nous venons exposer, en les groupant, les résultats obtenus depuis le dernier Congrès dans l'étude géologique de l'Indochine française, ce promontoire de l'Asie méridionale. Peut-être pourrait-on souhaiter qu'au moins pour les pays où l'exploration est encore peu avancée, les progrès successifs des recherches géologiques fussent ainsi notés par des sortes de mises au point qui permettraient de suivre l'avancement mondial de notre science.

Le dernier exposé synthétique de la géologie de l'Indochine—et en même temps le plus complet—est l'oeuvre de M. Jacob, ancien Chef du Service Géologique de l'Indochine et actuellement professeur à la Faculté des Sciences de Paris. Cet exposé a été rédigé en 1925 à l'occasion du jubilé du Professeur Verbeek.(1) Nous allons essayer de le compléter en suivant le même plan.

* * *

Le principal résultat obtenu depuis cette époque, résultat qui nous permettra d'ailleurs de rendre les autres plus clairs, est la publication de la *première carte géologique générale de l'Indochine française* dont nous donnons cijoint un exemplaire au 4,000,000 ème en noir.

Nous nous en voudrions de ne pas noter qu'en 1882, Fuchs a déjà donné une esquisse géologique au 6.000.000 ème de ce pays. (2) C'est d'ailleurs cette carte qui a été généralement reproduite ultérieurement par les auteurs qui se sont occupés de cette question et, en particulier, c'est elle que l'on retrouve dans la "Face de la Terre" de Suess.(3) Cependant cette esquisse, qui résultait d'une tournée extrêmement sommaire et de renseignements recueillis rapidement, aurait pu être améliorée dès 1904 par les

(1) Les renvois se rapportent à la Bibliographie placée à la fin de cette note; cette bibliographie fournit également les indications nécessaires pour poursuivre, si on le désire, une étude plus détaillée de la géologie de l'Indochine.

cartes publiées par M. M. LANTENOIS & DE LAMOTHE dans les Comptes-Rendus de la Société Géologique de France.

Il faut ensuite attendre jusqu'en 1921 où, à la suite des travaux des Collaborateurs du Service Géologique, mon éminent prédécesseur M. JACOB a donné une carte au millionième du nord de l'Indochine.([4]) Des recherches de M. M. FROMAGET ([8]) et BOURRET ([7]) ont étendu sensiblement cette carte vers le sud. Par contre le pays au sud de Tourane restait toujours plus ou moins inconnu comme le signalait M. JACOB en 1925 dans la synthèse rappelée plus haut.([1]) C'est à parcourir cette région méridionale que nous avons personnellement consacré notre temps de 1925 à 1928, de telle sorte que la carte que nous donnons adjourd'hui expose l'ensemble de nos recherches personnelles dont malheureusement les circonstances ne nous ont pas permis de donner une description détaillée.([11]) Il convient d'ajouter que, pendant ce temps, les autres Collaborateurs du Service poursuivaient la mise au point de feuilles régulières au 500.000 ème dans d'autres régions.([15])

Ayant ainsi très sommairement résumé l'historique de cette carte nous pouvons succinctement souligner ce qu'elle apporte de nouveau en suivant l'exposé de M. JACOB auquel il a été fait allusion plus haut.([1])

* * *

Nous n'avons pas introduit dans notre carte de divisions à l'intérieur des terrains anté-carbonifères. A la vérité, l'anté-cambrien est inconnu et le cambrien et le silurien sont probablement très réduits comme l'indique la brochure de M. JACOB.([1])

Le cambrien de l'extrême-nord du Tonkin (Chang-Poung) n'a pas été revu depuis lors; nous n'en connaissons pas ailleurs avec certitude, car de nouvelles recherches laissent planer quelques doutes sur l'attribution à cette époque de la petite bande signalée dans le moyen Tonkin par M. PATTE.([10])

Du silurien nous ne connaissons également que les petits affleurements tonkinois déjà signalés en 1925; nous mettons même en doute l'attribution des schistes de la région de Ban-Hom que nous rapporterions plutôt au dévonien inférieur. Par contre, on peut ajouter la base de la série siluro-dévonienne reconnue par FROMAGET.([1])

En résumé, ces terrains anté-carbonifères de la carte doivent être principalement dévoniens. Nous ne voulons pas surcharger cet exposé en donnant de longues listes de fossiles et nous renvoyons aux ouvrages originaux pour ces détails. Le dévonien de l'Indochine, principalement constitué par des schistes et des quartzites, contient, mais plus rarement, des horizons calcaires. Aux étendues dévoniennes déjà connues dans le nord du Tonkin, nos nouvelles études ont ajouté d'assez grands massifs de schistes parfois un peu métamorphiques très répandus dans le sud de l'Indochine, nous attribuons au même étage, les terrains anté-carbonifères du Cambodge signalés par de LAMOTHE.([6])

L'anthracolithique (carbonifère et permien) est un des premiers étages qui aient été reconnus en Indochine. Avant ces années dernières le carbonifère inférieur (dinantien et moscovien) paraissait assez douteux. Les études de FROMAGET(9) en ont révélé une belle faune dans le Nord-Annam. Par contre, l'ouralien et le permien étaient connus à l'état de calcaires à fusulines dont de nombreuses analyses ont été publiées; ces calcaires se retrouvent dans le sud de l'Indochine mais seulement à l'ouest d'une ligne passant grossièrement par Tourane et Phnom-Penh; au sud-est de cette ligne le pays paraît entièrement exempt de ces calcaires ouraliens et permiens. FROMAGET(9) a mis en écidence l'existence dans le Nord-Annam d'un autre faciès gréso-schisteux de cet âge et il est possible que cette remarque conduise plus tard à une révision de certaines déterminations stratigraphiques du nord.

Ce n'est pas ce seul caractère stratigraphique qui nous a conduit à séparer l'anthracolithique sur notre carte. Ainsi que nous le dirons plus loin, nos recherches récentes conduisent à mettre en évidence l'importance de cette époque dans l'histoire géologique générale: c'est une période de calme relatif séparant deux périodes d'orogénèse. Et d'ailleurs, en même temps, dans les pays où l'anthracolithique n'existe pas à l'état de terrains sédimentaires, on retrouve d'énormes masses de roches rhyolitiques dont nous parlerons un peu plus bas.

Notre carte ne porte pas de subdivision dans le secondaire: en fait celui-ci est surtout constitué par du trias et un peu de rhétien et de lias; aucun terrain marin plus récent n'existe en Indochine.

C'est surtout le trias qui est abondant dans le nord de l'Indochine; les études de PATTE (10) et FROMAGET (9) ont introduit plus de détail et de précision dans notre connaissance du trias indochinois avec de longues listes de fossiles bien caractérisés pour lesquelles nous demandons la permission de renvoyer aux travaux de ces auteurs.

Le rhétien qui était une des premières connaissances géologiques indochinoises par les traxaux paléobotaniques de Zeiller sur la flore des gisements houillers du nord de l'Indochine nous semble maintenant un peu moins sûr: un travail de révision que M. FROMAGET poursuit actuellement nous laisse actuellement dans l'incertitude sur le point de savoir s'il ne conviendrait pas de vieillir un peu une partie au moins de ces couches et de les rapporter au trias supérieur: certaines semblent en tout cas à peu près contemporaines des Napeng Beds de Brimanie.

On a signalé depuis longtemps deux gisements de lias marin en Indochine: l'un se trouve près de Tourane, l'autre près de Saigon. Le premier est connu en raison du gisement (rhétien) d'anthracite de Nong Son qui se trouve aux environs, l'autre est une belle découverte de M. LANTENOIS, aux chutes de Trian. Le gisement de Nong Son dit encore de Huu Nien a été étudié en particulier par M. BOURRET (7) qui a montré l'existence, au-dessus

des gîtes houillers continentaux ou lacustres, de grès fins dans lesquels avait été recueillie antérieurement par COUNILLON une faune hettangienne à Psiloceras. A Trian, des schistes gréseux ont fourni à M. LANTENOIS un Hildoceras toarcien. Dans ces deux régions, les terrains ne sont pas horizontaux, à Nong Son, ils forment un synclinal, relativement peu plissé dans l'ensemble avec quelques exagérations locales; à Trian les schistes gréseux sont assez redressés.

Nous attribuons à la même époque liasique des grès continentaux qui couvrent le moyen et le bas Laos, le bassin siamois de la Semoun et une partie du Cambodge. Ces terrains soulèvent bien des problèmes que l'avenir seul pourra résoudre. A l'heure actuelle nous pouvons cependant affirmer l'origine continentale de ces grès; l'irrégularité de la sedimentation, la présence très fréquente de stratification entrecroisée ne laisse guère de doutes à cet égard. Ces grès doivent sans doute leur formation, après l'émersion du début du secondaire, à un épisode analogue à celui que nous voyons se réaliser de nos jours dans les mêmes régions, où ils sont souvent recouverts de larges étendues d'alluvions sableuses.

On peut signaler également que ces grès sont salifères dans le nord (moyen-Laos) et contiennent au contraire du jais dans le sud, en particulier dans l'île de Phu-Quoc près de la côte du Cambodge où l'on fait une petite extraction locale.

Nous pouvons ajouter, en outre, que ces grès continentaux sont horizontaux dans l'ensemble. Cependant ils sont affectés de fractures importantes. C'est ainsi que, près de Kampot (sud du Cambodge), on peut voir la falaise du Bockor surplomber la mer de plus de 1,000 mètres en laissant ainsi la trace très nette d'une fracture.

Sur l'âge de ces grès, nous ne pouvons rien affirmer en l'absence de tout fossile: nous attribuons ces terrains au lias, parce que les terrains sous-jacents qu'ils recouvrent sont au plus du rhétien.

Si ces terrains sont bien liasiques, ils doivent se raccorder latéralement aux terrains marins du même âge que nous venons de signaler; mais jusqu'ici les explorations n'ont pas pu être menées dans les régions de raccord, d'accès très difficile.

Une autre particularité de ces grès est leur très grande épaisseur au moins dans certaines régions: c'est ainsi que dans le sud du Cambodge, cette épaisseur doit dépasser 1,000 mètres; une telle épaisseur de terrains d'origine continentale laisse entrevoir des problèmes tectoniques intéressants.

Nous ne dirons rien de particulier sur les petits bassins tertiaires lacustres déjà connus par les travaux antérieurs [1]. Nous voulons par contre attirer l'attention sur ces étendues alluviales que nous venons de signaler et que nous connaissons un peu mieux que nos prédécesseurs. La plus grande masse est située dans le sud, dans les deltas réunis du Mékong et du Donnai et autour des grands lacs du Cambodge, une autre étendue non négligeable est le delta

surpeuplé du Tonkin; enfin un liseré de 10 à 20 kilomètres de largeur suit la côte d'Annam d'une manière presque continue mais en se resserrant de plus en plus du nord vers le sud. Dans toutes ces régions notre analyse nous a révélé deux niveaux d'alluvions que nous appelons, pour faire bref, alluvions anciennes et alluvions récentes, sans que nous ayons d'ailleurs un moyen de préciser l'âge des alluvions les plus vieilles; par contre nous avons un moyen pétrographique très net de les séparer: les alluvions anciennes sont, presque sans exception, recouvertes d'une couche de latérite compacte appelée localement "bienhoa," tandis que les alluvions récentes sont inaltérées. La position relative de ces deux séries d'alluvions est d'ailleurs très variable avec les pays, mettant en évidence des mouvements du sol sur lesquels nous reviendrons plus loin. Au Tonkin et dans certaines régions du Nord-Annam, il est assez constant de voir les alluvions anciennes à 10 ou 12 mètres au-dessus des alluvions actuelles qui se sont par conséquent déposées dans les parties érodées des autres. Dans le nord de la Cochinchine la situation est identique, mains dans le sud par contre, ce sont les alluvions actuelles qui recouvrent les alluvions anciennes, ces dernières n'étant d'ailleurs connues que par certains sondages. L'épaisseur de ces alluvions peut être considérable. Dans le delta du Tonkin, les alluvions actuelles ont au moins 40 mètres d'épaisseur; des chiffres analogues pourraient être cités pour la Cochinchine: on voit ainsi l'importance des mouvements corrélatifs du sol: Il est inutile d'insister sur le fait que les alluvions actuelles continuent à s'accroître dans le delta du Fleuve Rouge au Tonkin et dans le delta du Mékong en Cochinchine par suite dè l'apport continuel de ces fleuves.

Nos recherches récentes ont montré une singulière extension—déjà pressentie par les auteurs précédents—des terrains cristallins dans l'Indochine su Sud.

Ce sont d'abord des granites que l'on peut séparer en deux séries: des granites relativement acides, au total semble-t-il moins abondants qu'on ne le pensait tout d'abord et représentant une forme très ancienne, au moins anté-dévonienne, de ces terrains; puis une série monzonitique plus abondante et que l'on peut peut-être dater au moins en partie de l'anthracolithique, représentant si l'on veut la forme profonde des éruptions rhyolitiques dont nous allons parler. Nous signalerons également l'existence dans le sud-est de l'Indochine, aux environse du Cap Varella, de cette forme pétrographique très spéciale de granite connue sous le nom de granite de Rapakivi.

Les premiers géologues indochinois ont été frappés par l'existence dans le nord de l'Indochine de grosses masses de roches d'épanchement acides que, pour simplifier, nous appelons rhyolites, mais dont la série s'étend jusqu'aux dacites. Le sud de l'Indochine a révélé des étendues bien plus considérables de ces roches, comme le montre notre carte. Les travaux actuellement en

cours poursuivront leur analyse pétrographique sur laquelle nous ne sommes pas encore en mesure de donner de grands détails. L'âge de ces épanchements est un problème qui divise les géologues indochinois. Ceux qui ont travaillé dans le nord du Tonkin, suivant en cela les idées de M. JACOB ([illegible]) ont une tendance à considérer ces rhyolites comme triasiques; les autres géologues les rapportent à l'anthracolithique, ainsi que nous le disions plus haut. Nous serions plutôt partisan de cette dernière thèse; la liaison avec des gisements fossilières triasiques signalée dans le nord-est du Tonkin ([10]) nous paraît moins évidente qu'elle avait semblé aux premiers auteurs; sans vouloir développer d'autres arguments, nous dirons que nous sommes frappé avec FROMAGET ([9]) de ce fait constant de l'incompatibilité des terrains sédimentaires anthracolithiques et des épanchements rhyolitiques; là où l'on trouve des terrains sédimentaires ouraliens ou permiens on ne trouve pas de rhyolites et réciproquement; nous pensons que les rhyolites correspondent aux parties émergées à cette époque lointaine tandis que les terrains sédimentaires — faciès calcaire ou faciès gréso-schisteux correspondent aux régions immergées.

Une autre découverte de nos travaux récents est l'extrême abondance dans l'Indochine du Sud de masses basaltiques d'âge probablement quaternaire. Notre carte essaie d'en préciser l'extension; leur existence a d'ailleurs généralement attiré l'attention récemment par leur altération en terre rouge latéritique si propice aux cultures tropicales. Ces grandes masses basaltiques correspondent très souvent à toute une série de volcans éteints dont on peut voir encore les appareils à peine démantelés par l'érosion. Signalons en passant la petite éruption sous-marine qui a fait surgir en 1923, au large du Sud-Annam, une île temporaire ([11]). Enfin, plus spécialement, M. LACROIX, lors de notre tournée commune de 1927, a bien voulu nous faire remarquer, dans le Sud-Annam, près de Dalat des affleurements intéressants qui fournissent une contribution importante au problème des "pépérites" du Plateau Central de France ([12]).

Les autres roches éruptives du type gabbro ou andésite n'ont pas été retrouvées par nos explorations du sud; nous n'avons donc rien à ajouter à ce que l'on connaissait antérieurement sur ce sujet.

Nos idées sur la tectonique de l'Indochine, profitant de l'impulsion que leur avait si merveilleusement imprimée M. JACOB, ont fait de très réels progrès depuis trois années. Déjà lors du Congrès précédent à Madrid en 1926, M. FROMAGET avait pu apporter quelques précisions; les recherches que nous avons entreprises nous-même, ainsi que celles de nos Collaborateurs et tout particulièrement celles de M. FROMAGET nous permettent de donner au tableau d'ensemble un dessin plus net.

Il convient tout d'abord de séparer l'Indochine en plusieurs zones qui apparaissent déjà assez clairement sur notre carte géologique générale, mais

qui sont précisées sur notre schéma tectonique. Toute la structure géologique de l'Indochine s'ordonne autour d'un noyau résistant situé dans le sud-est et que nous appelons le *massif central de l'Indochine.* Ce massif est principalement composé de terrains cristallins granite, gneiss ou micaschistes; à l'ouest et au sud il est couvert par des terrains que nous attribuons au dévonien et qui sont généralement des schistes plus ou moins métamorphiques souvent très redressés: il n'existe pas dans ce massif d'autres terrains sédimentaires, alluvions exceptées; en particulier il n'y existe aucun calcaire anthracolithique: on y rencontre, au contraire, les deux séries d'épanchements cités plus haut, épanchements rhyolitiques de l'anthracolithique, épanchements basaltiques récents. Tout laisse à penser que la moitié est de ce massif est effondrée sous la mer et le rivage est et sud de l'Annam conduit bien souvent à le considérer comme le résultat de fractures. Considéré au point de vue structural il paraît vraisemblable que ce bloc se prolonge en pointe vers le nord-ouest jusqu'au Haut-Laos, bien que les terrains cristallins correspondants n'affleurent pas à l'heure actuelle.

Il faut aller vers le nord jusque dans le Kwang-Tung et le Kwang-Si, c'est-à-dire sortir de l'Indochine, pour retrouver un autre môle résistant: il a été signalé depuis longtemps par BAILEY WILLIS et les géologues de Chine; vers l'ouest au contraire, c'est-à-dire vers le Siam et la Birmanie, nous nous dirigeons vers la chaîne tertiaire qui de l'Himalaya court vers les Etats Malais.

Ces premières constatations conduisent à faire des différences entre les deux régions suivantes: d'une part le pays situé entre le massif central de l'Indochine et le massif résistant de la Chine méridionale, c'est-à-dire le Tonkin et le Nord-Annum; d'autre part le pays situé entre le massif central de l'Indochine et la chaîne tertiare, c'est-à-dire le Cambodge, la Cochinchine, le Moyen et le Bas Laos. Enfin, il y a une sorte de point singulier à la rencontre de ces deux pays, c'est-à-dire dans le Haut-Laos.

Examinons séparément les deux pays que nous venons de distinguer. Le Tonkin et le Nord-Annam représentent donc un pays coïncé si l'on peut dire entre deux massifs résistants. Nos analyses nous conduisent à admettre que ces deux massifs se sont rapprochés à deux reprises avant que le pays intermédiaire ne soit suffisamment consolidé; une première fois au carbonifère inférieur, une seconde fois vers la fin du trias,, la région non stabilisée se rétrécissant naturellement d'une ·époque à l'autre: on peut ainsi distinguer en bordure du massif central, une région que nous appelons *région hercynienne du Nord-Annam* plus spécialement étudiée par FROMAGET ([2]); on peut penser qu'elle a son équivalent au sud du massif de la chaîne mériodionale, mais ce fait n'apparaît pas nettement en Indochine. La région hercynienne du Nord-Annam est consolidée, semble-t-il, depuis le carbonifère et c'est au nord, c'est-à dire au Tonkin, que l'on trouve la

zône encore instable dite *zône secondaire du Tonkin* qui a été l'objet de mouvements triasiques ou rhétiens.

La synthèse structurale de la région située à l'ouest du massif de l'Indochine nous apparaît moins clairement que celle de la région que nous venons d'esquisser, car nos explorations y sont moins avancées. Nous pouvons cependant en donner quelque idée. Nous n'avons pas de raison d'y distinguer une zône de mouvements hercyniens comme dans la région précédente; par contre nous devons admettre qu'elle a été l'objet de mouvements d'âge secondaire comme au Tonkin, car les calcaires carbonifères y sont fortement laminés; et nous attribuons à ces mouvements la constitution et la consolidation d'une *ride primaire du Laos et du Cambodge* très en évidence sur notre carte. Entre cette ride et le massif central s'étend un grand bassin qui correspond à l'heure actuelle à la vallée du Mékong et de son affluent siamois de la Semoun; c'est dans cet espace ainsi protégé que se sont déposés les grès continentaux d'âge probablement liasique et c'est pourquoi nous appelons cette région la *zône des grès continentaux*.

Dans une note antérieure ([11]) nous avions pensé que les terrains cristallins du massif central tels qu'ils affleurent à l'heure actuelle étaient entourés d'une ceinture de terrains marins liasiques qui joindraient ainsi du nord au sud les deux régions connues de lias marin de Tourane et de Saigon citées plus haut. Dans une étude récente, particulièrement intéressante présentée au Congrès Pacifique de Java, M. Fromaget a repris cette hypothèse et voit là le passage d'un synclinal d'âge secondaire qui viendrait de Hongkong et se dirigeait vers Bornéo. Nous ne croyons plus, quant à nous, à cette liaison et nous pensons, comme nous le disions plus haut, que les deux régions de lias marin se raccordent latéralement aux grès continentaux; nous voyons ces deux zônes de lias marin comme des golfes ouverts vers ce qui est encore la mer à l'heure actuelle. C'est pourquoi nous étendons la région des grès continentaux jusqu'aux affleurements cristallins du massif central. Faute d'explorations suffisamment détaillées, il nous est impossible d'affirmer qu'une thèse est préférable à l'autre; notre opinion est basée sur un certain nombre d'observations encore trop peu nombreuses pour entrainer une certitude. Nous avons voulu simplement signaler ici cette différence d'interprétation, car l'hypothèse de M. Fromaget entraîne un schéma structural autre que la nôtre: au lieu d'un seul bloc consolidé s'étendant, comme nous l'annoncions plus haut en pointe vers le nord-ouest jusque dans le Haut-Laos, il faudrait voir deux blocs distincts séparés par une zône instable qui serait justement le synclinal secondaire envisagé par notre distingué Collaborateur qui appelle ces deux blocs la Laosia, au nord-ouest, et l'Annamia, au sud-est.

Le Haut-Laos où finit l'influence du bloc ancien du massif central de l'Indochine est, comme nous le disions plus haut, un point singulier d'où

divergent toutes les lignes de structure. Déjà les synthèses de M. JACOB([8]) y avaient signalé des singularités, précisées pour la région orientale par FROMAGET. ([13])

Cette division territoriale posée et complétant ce que nous avons dit plus haut de la stratigraphie et de la pétrographie indochinoise, nous pouvons aborder l'exposé de l'histoire géologique de ce pays.

De l'histoire anté-dévonienne nous ne savons rien; nous ne savons pas grand chose non plus de l'histoire dévonienne sinon que tout le pays devait être à peu près complètement immergé, sauf peut-être quelques ilôts du massif central.

Par contre avec le carbonifère nos idées deviennent beaucoup plus précises: l'époque du carbonifère inférieur (diantien et moscovien) est, comme on l'avait déjà pressenti mais comme FROMAGET ([9]) en a apporté des preuves indubitables, une époque d'orogenèse. Dans la région hercynienne du Nord-Annam nous voyons naître d'abord une ride dirigée vers le nord-ouest, cependant que le pays situé en arrière, c'est-à-dire au nord-est, se décolle et est traîné sur l'avant-pays, c'est-à-dire vers le sud-ouest, recouvrant ainsi par des schistes cristallins, du silurien et du dévonien, un autre dévonien différent et autochtone. Des phénomènes analogues ont dû se passer plus au nord, mais ils sont masqués par les mouvements plus récents: c'est d'ailleurs pourquoi cette phase d'orogenèse n'a pu être mise en évidence que récemment, les premiers travaux géologiques ayant surtout porté sur le Tonkin.

A ces mouvements fait suite une période de calme relatif pendant l'ouralien et le permien. C'est pendant cette période de calme que se déposent dans les bras de mer les calcaires à fusulines ou les sédiments gréso-schisteux que nous avons signalés plus haut, cependant que sur les régions émergées et en particulier sur le massif central, s'épanchent les énormes masses de laves rhyolitiques dont nous avons indiqué plus haut l'importance.

Puis le travail reprend au trias et surtout au trias supérieur et au rhétien. C'est là un des résultats principaux de nos recherches récentes. Ces mouvements ont été signalés depuis longtemps au Tonkin et tout spécialement par M. JACOB ([1]) qui en a donné une magistrale synthèse; mais jusqu'à ces dernières années on avait tendance à considérer ces mouvements comme tertiaires, contemporains des mouvements himalayens. Nos travaux récents ont établi avec certitude que ces mouvements datent du début du secondaire. Dès 1926 nous avons été frappé du fait que l'Indochine étant émergée depuis la première moitié du lias, il était peu vraisemblable que ces terrains émergés eussent subi des déplacements horizontaux importants à la surface du sol: les recherches des Collaborateurs du Service Géologique et tout spécialement de PATTE ([10]) et de FROMAGET ([9]) ont confirmé nos prévisions: ils ont pu montré la superposition en discordance sur le trias

supérieur ou le rhétien, plissé, renversé ou charrié, de terrains au plus liasiques, absolument tranquilles et horizontaux.

Si nous avons obtenu ce résultat d'ensemble, nous sommes loin cependant de pouvoir donner des précisions de détail; et il est vraisemblable qu'il faudra reprendre et assouplir certaines synthèses détaillées parues précédemment. C'est ainsi que l'on a admis jusqu'ici que la poussée principale, au moins au Tonkin, était dirigée vers le sud-est; nous en sommes moins sûr à l'heure actuelle; et tout en reconnoissant l'existence d'un tel mouvement nous serions portés à nous demander si la poussée principal n'est pas plutôt vers le sud-ouest, conforme par conséquent au plan hercynien antérieur; ou même nous nous demandons s'il y a lieu de parler d'une direction générale de poussée et s'il ne faut pas plutôt voir dans ces mouvements le résultat, irrégulier dans le détail, du rapprochement des deux masses solides dont il a été questions ci-dessus. De même on a décrit dans certaines régions plusieurs empilements de nappes: peut-être faudra-t-il ne plus voir qu'une seule nappe principale dont l'érosion agissant depuis le début du secondaire n'a plus laissé que des lambeaux épars, tandis que le reste ne doit s'interpréter que comme de simples écailles. Tous les géologues qui ont travaillé dans les pays tropicaux comprendront nos hésitations et nos corrections successives: il s'agit d'un pays très étendu, plus grand que la France, qui n'est ouvert à la colonisation européenne que depuis une cinquantaine d'années, où les voies de communication sont encore relativement peu denses et où le géologue est perdu dans une brousse impénétrable tandis que les rares affleurements qu'il peut voir sont généralement très profondément altérés.

Quoi qu'il en soit il n'est pas douteux que le Tonkin ait subi des mouvements orogéniques secondaires très violents qui se sont traduits soit par des superpositions anormales incontestables trainant d'énormes étendues de calcaires carbonifères sur les schistes triasiques soit par des masses puissantes de roches écrasées et laminées. Ce sera le travail de demain de mettre autant que possible de l'ordre dans ce chaos.

Ces mêmes mouvements secondaires déjà très étudiés au Tonkin et dans le Nord-Annam sont également manifestés quoique moins bien connus dans les autres zones analogues. Dans le Haut-Laos, M. Jacob (¹) a signalé de nombreux écrasements et des superpositions anormales. Au Cambodge, les calcaires carbonifères nous ont montré des laminages intenses. Là également l'avenir nous apportera des précisions.

Nous pouvons donc dès maintenant affirmer l'existence de deux périodes d'orogenèse principales en Indochine, l'une au carbonifère inférieur, l'autre au trias supérieur-rhétien. L'une et l'autre se sont traduites par des déplacements horizontaux considérables et ont droit ainsi d'entrée dans les grandes séries des mouvements géologiques. L'une et l'autre ont pressé

l'ensemble du pays de l'Indochine autour du massif central résistant, moulant ainsi tous les terrains sédimentaires autour de lui.

Après ces efforts du trias supérieur et du rhétien, le bloc indochinois émerge et entre dans une période de calme: les derniers terrains marins, nous l'avons dit, s'étendent dans deux petites pointes vers Tourane et Saigon et appartiennent à la première moitié du lias; au centre de l'Indochine se dépose la masse des grès continentaux.

On ne peut pas ne pas rappeler ici que ces régions de lias marin ont subi, comme nous le disions plus haut, quelques plissements, d'ailleurs semble-t-il assez faibles sauf peut-être certaines exagérations locales. Comme, d'autre part, les grès continentaux qui semblent bien de même âge sont horizontaux, on est conduit à penser que dans ces deux golfes marins sont venus mourir certains mouvements postliasiques dont nous ne connaissons pas d'autre équivalent, mais que l'on retrouve en dehors de l'Indochine, dans l'Extrême-Asie méridionale.

Il convient également de rappeler ici la grande épaisseur (plus de 1,000 mètres) des grès continentaux. Cette épaisseur qui est un minimum, en raison de l'érosion qui a dû se produire ultérieurement, exige que le bassin fermé dans lequel se déposaient ces grès se soit enfoncé lentement mais cependant assez profondément de manière à permettre cette accumlation de sédiments. Ce sont là également des mouvements postérieurs aux grands mouvements qui ont donné lieu aux charriages du Tonkin.

Les mouvements tertiaires hymalayens, s'ils ne se sont pas traduits comme on le pensait antérieurement par de grands charriages, ont cependant laissé leurs traces dans l'édifice indochinois; c'est à eux qu'il convient de rapporter soit de grandes cassures dirigées généralement nord-ouest soit un gauchissement de tout le pays. Les cassures, dont le réseau hydrogaphique souligne l'importance et la constance, sont jalonnées par les bassins tertiares, eux-mêmes faillés, qui donnent bien l'âge des premiers mouvements; le gauchissement est indiqué, entre autres, par la disposition relative des deux séries d'alluvions que nous signalions plus haut. Il nous paraît vraisemblable de rapprocher ces mouvements des éruptives basaltiques considérables du sud-indochinois.

Stratigraphie, pétrographie, tectonique, telles sont les trois parties dont nous venons d'esquisser les progrès accomplis depuis la magistrale synthèse de M. Jacob [1]. Depuis cette époque, en particulier sur les conseils et avec l'aide de M. Lacroix que nous avons eu le très grand honneur d'accompagner lors d'une tournée de deux mois qu'il a effectuée en 1927 en Indochine, notre attention s'est portée également sur une autre série des phénomènes que nos prédécesseurs n'avaient pas eu le loisir d'étudier en détail: *l'altération des roches* sous le climat tropical de l'Indochine. Nous avons

donné ailleurs un premier compte-rendu sommaire ([11]) ou une étude plus détaillé ([12]). Nous coulons simplement souligner ici les premiers résultats.

On sait que les auteurs—peu nombreux d'ailleurs—qui ont eu à s'occuper spécialement de cette question de l'altération des roches ont distingué deux types d'altération que les ouvrages classiques présentent l'un, comme spécial aux pays à climat tempéré, l'autre comme se présentant dans les pays à limat tropical. Il serait sans doute plus exact de séparer ces deux types extrêmes d'altération par le fait que l'altération s'arrête ou dépasse le type argileux: dans le premier cas, que nous appellerons *altération ordinaire*, les silicates d'alumine et tout spécialement les feldspaths se transforment en argile qui, elle, reste intacte; dans le second cas, que nous appellerons avec M. Lacroix, *altération latéritique*, l'argile ainsi produite est elle-même attaquée et décomposée en alumine qui reste sur place et en silice qui est éliminée.

On nous permettra également d'insister sur le fait que l'Indochine française est située entre l'équateur et le Tropique du Cancer, en moyenne à la latitude du Sénégal. Son climat est nettement tropical avec en particulier l'alternance d'une saison sèche et d'une saison humide et une température qui, exceptionnellement au Tonkin, peut varier entre 10° et 40° centrigrades mais qui, en Cochinchine, reste généralement au voisinage de 20° centigrades.

Un des faits les plus curieux à signaler est qu'en dépit de ce caractère nettement tropical du climat de l'Indochine, les altérations des roches sont très loin d'appartenir toutes au type latéritique; bien mieux nous dirons que nous ne connaissons pas d'exemple de ce type à l'état pur. C'est ainsi que les granites se décomposent comme en Europe en arènes sableuses; et si les rhyolites, les basaltes et d'une manière générale les roches laviques nous donnent bien des types latéritiques avec concentration de l'alumine et du fer et élimination de la silice, le phénomène n'est jamais complet et l'altération comprend toujours une partie assez importante d'argile non décomposée.

Un autre phénomène non moins curieux est celui-ci: nous avons dit plus haut que les alluvions anciennes sont très généralement recouvertes d'une couche de latérite compacte appelée en Indochine "Bienhoa" tandis que les alluvions récentes en sont exemptes: c'est donc que ce type de latérite ne se produit plus à l'heure actuelle tandis qu'il s'est formé autrefois dans les mêmes régions. Au contraire la forme terreuse, non compacte, de la latérite d'autres roches—généralement une terre plus ou moins rougeâtre—semble bien se former encore de nos jours. Cette différence dans la formation de ces deux types de latérite est un des problèmes les plus intéressants que nous ayons à envisager à ce sujet.

L'épaisseur de l'altération en est un autre: car suivant les régions et sans qu'on puisse l'attribuer à des causes extérieures telles que l'érosion ou le changement de climat, l'épaisseur est extrêmement variable pour un

même type de roches: un mètre ou moins dans certaines régions, plus de quinze mètres dans d'autres.

Nous ne sommes encore qu'au début de ces recherches et nous espérons au prochain Congrès apporter des précisions plus importantes.

Tel est, sommairement résumé, l'état actuel de nos connaissances sur la géologie indochinoise: les géologues actuellement présents au Service Géologique de l'Indochine se devaient, aussi bien vis-à-vis des Maîtres qui les ont précédés dans cette carrière ou qui les ont guidés dans leurs travaux que vis-à-vis du Gouvernement Général de l'Indochine qui leur fait confiance en mettant à leur disposition des crédits relativement importants, de faire connaître les progrès réalisés par leurs efforts depuis les trois dernières années écoulées. Ils sont heureux, en présentant ces résultats, de pouvoir exprimer au Congrès Géologique International leurs vifs sentiments de gratitude pour l'attention avec laquelle il veut bien suivre depuis quinze ans le développement des travaux accomplis en Indochine.

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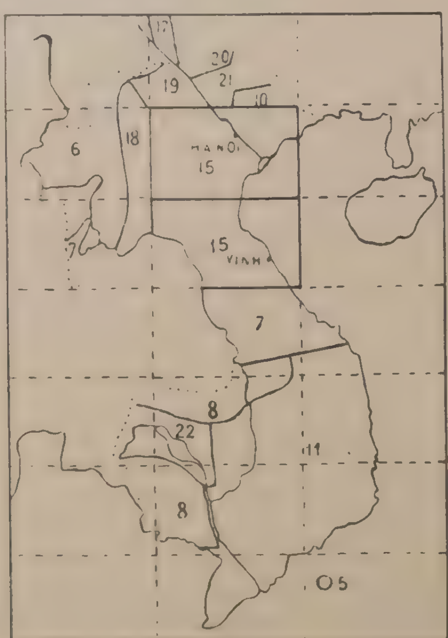
La carte ci-dessous indique l'ouvrage à consulter pour obtenir les renseignements les plus récentes et les plus complets sur la région correspondante. Les numérous renvoient aux ouvrages précisés ci-après qui comprennent en outre les ouvrages cités dans le texte.



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50. SUR LA TECTONIQUE HERCYNIENNE DU MASSIF CENTRAL FRANCAIS A L'EST DE LA LOIRE

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La découverte du granite écrasé de Montrambert et de la Gampille aux environs de St-Etienne, faite en 1906 par MM. TERMIER et FRIEDEL a posé pour les Cévennes un problème tectonique nouveau. Dès 1907 MM. TERMIER et FRIEDEL attribuent à une nappe charriée les gneiss granulitiques des Cèvennes et admettent l'existence d'une nappe supérieure qui comprend en particulier le granite de la Gampille. Pourtant en 1910, MM. FRIEDEL et GRANDJEAN rattachaient les gneiss granulitiques à l'autochtone et distinguaient par contre trois nappes, une nappe supérieure qui coïncide en partie avec la nappe supérieure de MM. TERMIER et FRIEDEL, une nappe de micaschiste, enfin une nappe de granite écrasé dont il subsisterait seulement un petit lambeau près de St-Just-sur-Loire.

A partir de 1922, je repris l'étude du massif du Pilat puis celle des chaînes du Pyfara et de la Roche-de-Vent où M. F. BLONDEL avait admis entre temps avec des modalités assez différentes l'existence de mouvements tangentiels. La méthode adoptée pour ces recherches de tectonique cristallophyllienne et cristalline comporta la détermination des faciès éruptifs et cristallophylliens antérieurs aux mouvements principaux, puis une analyse statigraphique détaillée qui définit des horizons cristallophylliens indépendamment de toute hypothèse tectonique, enfin l'étude des phénomènes dynamiques (déformations et écrasements) et l'interprétation de la structure apparente qui traduit dans une certaine mesure la structure vraie, par exemple celle d'un pays de nappes ou de racines.

Dans le massif du Pilat et dans les chaînes cévenoles plus méridionales, on voit ainsi que les granulites (granites à deux micas) sont postérieures à l'écrasement et par suite au charriage du cristallophyllien. Les gneiss granulitiques des Cévennes résultent de l'imbibition d'une série cristallophyllienne antérieure qui comprend plusieurs horizons de gneiss oeillé et

des horizons de gneiss à mica noir associés parfois à du granite. Il ne peut alors être question au sens strict du charriage des gneiss granulitiques, mais des mouvements qui les ont affectés avant la granulitisation. En fait la complexité tectonique de cet ensemble est démontrée par la répétition de gneiss oeillés à grands feldspaths laminés, par les phénomènes d'écrasement que masque en partie la recristallisation post-tectonique, enfin par la position relative anormale des faciès catamétamorphiques et mésométamorphiques. On distingue ainsi au dessus du granite ou du gneiss granitoide autochtone quatre nappes superposées: nappe des Trois-Dents ou des gneiss oeillés inférieurs, nappe de Pouvardière qui contient des amphibolites, des gneiss à mica noir fissiles, compacts ou granitoïdes et souvent même du granite, nappe du Pilat qui contient des gneiss oeillés à la base, des gneiss feuilletés à mica noir au sommet, nappe de Laval à laquelle appartiennent tous les micaschistes de la région de St-Etienne et qui se complète sa base par des gneiss à mica noir et par des gneiss oeillés, exceptionnellement par du granite.

Les élèments de ce complexe tectonique cévenol affleurent dans le massif du Pilat et dans une large bande au sud du bassin houiller de St-Etienne, puis dans la bande synclinale Malleval-St-Marcel-Roche de Vent et dans le lambeau du Pyfara, enfin plus au sud jusque dans la région de Privas dans d'autres lambeaux. Les nappes ont donc couvert un domaine qui s'étend sur une soixantaine de kilomètres en direction axiale et plus encore en direction diamétrale. Les caractères lithologiques de trois nappes inférieures évoquent l'existence d'un pli couché puissant dont les gneiss oeillés du Pilat et ceux des Trois Dents seraient le flanc normal et le flanc inverse et dont les gneiss à mica noir ou le granite de la nappe de Pouvardière constitueraient le noyau. Mais les eléments de ce pli se sont décollés et ont cheminé les uns sur les autres en donnant naissance à trois nappes distinctes. Les nappes cévenoles sont donc des nappes du second genre ou nappes cassantes qui rappellent par certains caractères les grands plis couchés de style pennin c'est-à-dire les nappes du premier genre. Le charriage des nappes est sûrement antéstéphanien et probablement viséen ou postviséen. Les mouvements d'une seconde phase ont plissé les nappes et les formations stéphaniennes qui s'étaient déposées dans l'intervalle.

La terminaison en biseau et le raccord progressif des trois nappes inférieures au nord du massif du Pilat, qui ne traduisent pas un véritable enracinement, semblent prouver du moins que leur origine est au nord ou au nord-ouest sous la nappe de Laval. D'autre part les micaschistes de cette nappe ont dans la région de Saint-Etienne une structure isoclinale accusée à la fois par les pendages, par la puissance supérieure à celle des trois autres nappes réunies, enfin par l'existence d'une surface de poussée qui partage la nappe en deux écailles. Ces micaschistes plongent sous les gneiss ou granites lyonnais tout le long d'une ligne qui va des terrains récents du

Forez jusqu'à ceux de la vallée du Rhône et constituent une sorte de synclinal couché. Ce synclinal et la nappe de Laval sont une seule et même chose comparable dans un certain sens au grand synclinal de flysch des Alpes occidentales. On est ainsi conduit pour cette nappe plus sûrement encore que pour les nappes inférieures à l'idée d'un mouvement dirigé du N.W. vers le S.E. L'origine de la nappe, qui s'enracine en apparence à la limite septentrionale du domaine cévenol, doit être en fait au nord de cette limite sous les éléments lyonnais.

Au nord des nappes cévenoles, le domaine lyonnais (granite, gneiss, phyllades) comprend des plis redressés où la disposition isoclinale et à peu près constante. Les massifs granitiques de Chassagny et de Soucieu sont eux-mêmes nettement déversés sur le cristallophyllien et parfois écrasés à leur bordure sud-est. Ces plis aigus sont antéstéphaniens et postgranitiques comme les nappes cévenoles et semblent bien appartenir à une même phase tectonique. Pendant cette phase qui est la phase hercynienne principale pour le Massif central Français, c'est une même poussée dirigée du N.W. vers le S.E. qui a dans le domaine lyonnais plissé à plis aigus le cristallophyllien et déversé le cristallin sur le cristallophyllien et qui a d'autre part, provoqué un mouvement d'ensemble de ce domaine et donné ainsi naissance aux nappes cévenoles. Le lambeau de granite de la Gampille qui, près de Firminy, occupe au-dessus des micaschistes une position tectonique identique à celle des élèments lyonnais est sans doute un fragment du Lyonnais charrié sur la plus haute des nappes cévenoles. L'affinité de ce granite avec les granites porphyroïdes lyonnais apporte une présomption sérieuse en faveur d'une telle hypothèse et confirme ainsi l'interprétation générale.

Si l'on examine maintenant dans son ensemble la partie du Massif Central Français située l'est de la Loire on aperçoit depuis le Morvan jusqu' aux montagnes de l'Ardèche trois grandes zones tectoniques.

1°—La zone morvano-roannaise où existent saus doute des gneiss archéens ou précambriens et où le paléozoïque antéstéphanien partiellement métamorphosé et le granite qui le traverse ont été ployés en plis larges habituellement symétriques. Dans la région de Tarare où les mylonites viséennes ont été, signalées d'abord par M. Alb. Michel-Levy, je vois non pas des lambeaux de nappes, mais des écailles à plongée N.W. qui traduisent un mouvement d'ensemble de toute la zone vers le sud-est sur la zone lyonnaise.

2°—La zone lyonnaise caractérissée par la transformation complète du paléozoïque, par le passage brusque des schistes faiblement métamorphiques aux gneiss largement cristallisés, enfin par des plis aigus habituellement isoclinaux déversés vers le S.E.

3°—La zone cévenole caractérisée par un métamorphisme encore plus complet et plus régulier et par le passage insensible du granite au cristal-

lophyllien, enfin par la formation d'un système de nappes qui ont cheminé du N.W. au S.E.

Au contraire, au nord du Morvan, dans le géosynclinal ardennais et rhénan, la pousée s'est exercée vers le nord-ouest dans la direction de l'avant-pays septentrional. Ainsi apparaît pour la chaine hercynienne d'Europe occidentale, une idée toute nouvelle, celle de poussées inverses de part et d'autre de la zone morvanoroannaise qui serait le géanticlinal médian d'une chaine doublement déversée. Dans une coupe plus orientale, de part et d'autre du panneau Barrandien de Bohême on retrouve une disposition identique[1] qui semble être un caractère essentiel du rameau hercynien varisque depuis l'Espagne jusqu'en Russie.

[1] A. Demay—Comptes-Rendus de l'Académie des Sciences de Paris, 1929.

60. AN OUTLINE OF THE GEOLOGY OF PORTUGUESE EAST AFRICA.

BY

C. FREIRE DE ANDRADE.

INTRODUCTORY.

By permission of His Excellency the Minister of the Portuguese Colonies and of his Excellence the Governor General of Mocambique, this summary of the work of some of the Portuguese geologists in this colony, such as GENERAL SIR ALFREDO A. FREIRE DE ANDRADE, is published in the general interest in a language better known in the scientific world than Portuguese; and it was also thought that the publication of an outline of the geology of Portuguese East Africa would be welcome as there was already sufficient data collected by Portuguese and foreign geologists for that purpose.

Even for this general account of the geology of the colony it was necessary to obtain data from very different sources, in all scarcely sufficient for a provisional outline.

There are many problems awaiting solution that cannot be solved without further field work and a better delimitation of the outcrops of the different systems.

The bibliography for this outline is mentioned in "*Esboco Geologico da Provincia de Mocambique*"—Lisbon 1929, by the same author.

PHYSICAL FEATURES.

Portuguese East Africa is on the east coast of Africa, between latitude 26° 50' S. and 10 30' S., and on the west extends to the Union of South Africa and Rhodesia.

The area of the territory is approximately 295,000 square miles, about nine times that of Portugal.

The country may be broadly divided in lowlands, middle and high plateaux and mountains.

The lowlands, rising up to 500-600 ft., are broad in the south of the territory; they reach the Lebombo range to the west and become very wide about latitude 22 S.; further north they form the Urema plains and the course of the Zambezi river further inland, up to Lupata Gorge. Northward again they form a narrow coastal belt. The middle plateau, with an average elevation of 800-2,000 ft., rises from the low plains very rapidly and forms the core of the Manica and Sofala territory, covering practically all Tete district, from Lupata Gorge westwards, and nearly all Quelimane, Moçambique and Nyassa districts, although here the slope is not so marked from the coastal lowland. "Inselbergs" are found rising above the gentle undulating surface of this plateau, some of them, as the Gorongoza, the Namuli, the Chica, the Inago and other mountains in the north, form very important isolated peaks with altitudes ranging between 6,000 to 8,000 ft. above sea level. The step-like slope that divides the lowland from the middle plateau, after crossing the frontier near Chiomo, follows a N.E.-S.W. direction for some distance, having a general trend N.-S. beyond Vila Machado. This is the direction of the mountain ranges near the coast in Nyasaland, which form the eastern boundary of the plateau. On the frontier, a very important range, running N.-S., with altitudes between 6,000 and 7,000 ft., forms the limit of the high plateaux of South Africa and East Africa.

Some rivers, as the Limpopo, Save and Zambezi, cut deep gorges far back into the high and middle plateaux, the first two in British territory and the Zambezi, partly in Portuguese and partly in British. The other rivers also cup deep valleys on their way to the sea, descending from the plateaux in cataracts and rapids.

To the north of the Zambesi there are no important rivers, except in the north-west, drained by the Lugenda and other tributaries of the Rovuma.

Geology.

The investigation of the geology of Portuguese East Africa is no easy undertaking owing to the great extension of the territory and the difficulties that arise from exploring a tropical country where the thickness of vegetation, the climate and lack of good communication makes it very expensive and arduous. Much has been done, but not enough to furnish a thorough knowledge of the typical features of the geology of this country.

In the Geological Map shown, the different formations are coloured in even where the facts are scarce, but areas are left blank where we have no information.

The limits are therefore approximate, and will be modified by the new data obtained in every year's work. The Portuguese Government has a

Mining Department in the colony, that is making a systematic survey and it is hoped that in a few years the geological map will be considerably improved.

In Portuguese East Africa the sediments and volcanics are divided into different systems as far as it is possible, according to the present knowledge of the relative age of the several strata; the classification aims at a systematic correlation of the different strata.

Pre-Cambrian systems, granites and gneiss, form nearly two-thirds of the surface of the colony, and about one-third consists chiefly of modern rocks, sands that in part cover the Cretaceous and Tertiary rocks; the other systems have small importance.

Fossils have not been found in rocks older than the Karroo system, and therefore it is difficult to correlate these sediments.

The rocks younger than the Karroo system, are mostly marine deposits that invaded the lowlands of the coast, covering one-third of the Province.

The systems will be described in ascending order.

Primitive Systems, Granite and Gneiss.

The archaean rocks that form the basement complex of the colony are schists, sandstones and conglomerates. Only patches of these sediments remain in the hilly part of the country, on the surface of the granitic rocks formed after their deposition.

These archaean rocks are, in some places, very much folded, having a general N.-S. strike; however, there are some that strike perpendicular to this direction.

The sedimentaries are more abundant in the high mountains of Manica and Sofala territory, although they are also located near Vila Machado, near the coast in the Mocambique district, and in the northern parts of the Tete district. They consist mostly of "green stones," micaschists, chlorite-schists, talc-schists, argillaceous schists and phyllites, that are found in nearly all of these areas, while some of them consist of a series of sandstones, quartzites and conglomerates that form the upper portion of these systems, as in Macequece and Roguera. Crystalline limestone and white marble are found very often, interfoliated in gneiss and other metamorphic rocks, as in the Manica and Mocambique districts.

The rocks of the Chimanemane mountains are chiefly argillaceous schists, quartz-schists and quartzites, highly folded near the western fault, in British territory, but dipping east slightly and regularly in our country.

All these old sedimentaries are cut by dykes of dolerite and aplite that hardened the schists near the contacts. Tuffs and breccias are also found in intimate relation with these intrusive rocks. Most of the schistose areas are small and protected from erosion by block faulting or by the folds of the gneissic rocks.

Specially in Manica and Tete, minerals of economic value such as gold (sometimes argentiferous), copper, manganese, wolfram, galena, cassiterite, graphite, bauxite, etc., occur in veins and disseminated in the sedimentaries. Most of the hilly country of Moçambique colony, consists of granites, gneiss and associated rocks, surrounding the archaean and intrusive in those sedimentaries which were altered by them.

The granites consist of white felspar, quartz and very little biotite, and the rock is of a light greyish colour. The gneisses are darker on account of the more abundant biotite, and the gneissic banding may be coarse or fine.

Dykes of pegmatite and aplite, of a very light colour, appear very often near the contacts.

Amphibolites, pyroxenites, eclogites and metamorphic forms of these rocks, occur in the gneissic regions of the colony.

Granites and gneiss build up the "Inselbergs," common in the middle plateau, rising abruptly from the gneissic plains.

The contacts between these igneous rocks and the primitive schists, are very often metalliferous, but economic minerals are less frequently found in the granite-gneiss regions; yet graphite occurs in the Companhia de Moçambique territory, in the Tete district and in Nyasaland. Mica, iron, lead and gold also occur, either in dykes or in granites and gneiss.

There are some igneous rocks, undoubtedly younger than the old granites and gneiss, in many places within the colony. They are chiefly hornblende-granites, sometimes with pegmatitic structure, but it is common to find associated syenites, gabbros, diorites, dolerites and other rocks.

There are two large areas of modern granites in the Province, the Gorongoza Mountains and part of the northern regions of Tete district, and some smaller ones. Gabbros occur chiefly in the Manica and Sofala territory and in the Tete district.

Umkondo System.

This system forms a very small part of our colony, occurring mostly in Rhodesia and in the high plateau of Melsetter. In Moçambique province it appears in Spungabera and north of Chimanemane mountains, near Mount Zuira. The rocks of this system are chiefly sandstones, quartzites, argillaceous schists and phyllites. The last two form the base of the system and have purple and rose colours. Dolerite dykes and diorites are intrusive into the rocks of this system.

Karroo System.

In Moçambique the earliest fossils occur in sediments belonging to this system which is also the first to be correlated with European beds

Rocks of this system outcrop in small areas in Portuguese East Africa. Close to the Lebombo mountains and near the Massitonto river, there are sandstones, altered to quartzites near the contact with the Lebombo porphyries. These rocks are very similar to the Tete sandstones of the Karroo, and probably belong to the top of the system.

At Chiomo Karroo beds are also found; they comprise carbonaceous shales, conglomerates and sandstones, some of chocolate colour. Up to the present time a seam of coal, of poor quality, has been found near the base of the series.

These sedimentaries disappear under the Stormberg lava flows, that cover a large area south of Chiomo and therefore it is possible that coal will be under them.

To the north, there is a narrow strip of Upper Karroo beds bordering the granite-gneissic area of Manica and Sofala district, beginning at Sangadze river, to join in Tete a larger area of Karroo rocks.

The Stormberg lavas are seen again to the east of Gorongoza mountains, in a narrow strip that terminates near Catumba, overlying the Karroo sandstones belonging to the Stormberg.

The Karroo sedimentaries of Tete belong to the Upper Ecca, Beaufort and Stormberg Series, overlying granite and gneiss. In the Upper Ecca are found shales, sandstones and coal beds; the glossopteris flora consists of *Glossopteris indica, Glossopteris browniana, Schizoneura africana, Sphenopteris lobifolia, Glossopteris Brancai, Gangamopteris*, etc., showing a transition to the Beaufort Series, which consist chiefly of the "Tete sandstones"? having some limestone beds on the top; overlying these rocks, there are compact, greenish to white shale beds, containing some *Vertebraria* and *Radicites*.

The Stormberg rocks are chiefly sandstones which, in the Batonga region, are interbedded with lava flows towards the top of the Series. In the large area of Karroo beds south of the Zambezi river and between Chicoa and Zumbu, besides sandstones, conglomerates and shales, there are also some coal beds and basaltic lavas, the latter being near Luia river.

The Lupata basalts, crossing the Zambezi river below Tete, are not so wide and important as the southern basaltic lavas.

Karroo rocks are found also in Portuguese Nyasaland, near Litule and in the north-west of this territory. In Litule there is a small area of shales and sandstones and coal seams, reported to be of impure character, and in the north-west shales, sandstones and limestones and some carbonaceous shales, crop out over a very large rea. Intrusions of dolerite dykes, cut the Karroo rocks of Chiomo, Tete and Chicoa.

After the outpouring of the Stormberg lava flows, there was a period, before Cretaceous times, of eruption and deposition, which may also represent part of the Jurassic system.

The porphyries, granophyres and rhyolites of the Lebombo, as well as the porphyrites of Lupata and Luia, are probably of this period, while at Lupata Gorge, overlying the Stormberg lavas and covered by porphyrites, there are some conglomerates and sandstones with a reddish, brownish, yellowish or light colour.

Cretaceous System.

A series of reddish conglomerates and sandstones, that lie on the igneous and sedimentaries of probable Jurassic age, and sometimes in relation with the fossiliferous Aptian beds, crop out on the eastern Lebombo slopes, also in Batonga, Buzi, Cheringoma and Sena districts and, although they are probably of different ages, they have similar lithological aspect, being probably the traces of a transgression, in Cretaceous times, going in a N.N.W. direction up to the Zambezi valley, near Tambara.

They were considered of a Cretaceous age, although no fossils were yet found in them, but their stratigraphic position and the igneous pebbles found in the conglomerates, point to this position in the stratigraphical scale.

There are other outcrops belonging to the Aptian series, near Lourenco Marques, consisting chiefly of sandstones and limestones. In the Mocambique district, are found some shales and limestones; the Buzi and Cheringoma plateaux are chiefly made of Tertiary rocks, but at their base, there are some fossiliferous beds of Danian and older date.

In the southern part of the Tete district and close to the Luia river, there are some outcrops of reddish sandstones, conglomerates and shales, that are younger than the lavas of this region, as some porphyrite pebbles were found in them. If the lava flows are post-Stormberg, then these sediments must be younger and probably of a Cretaceous age.

Cretaceous rocks outcrop on the coast of Mocambique district and Portuguese Nyasaland, from Mongicual up to Pundanhar, near Rovuma. These sedimentaries consist chiefly of limestones, sandstones and some shales; in some of these limestones occurs a gigantic form of ammonite, *Pachydiscus* (?) *Conducensis* Choffat, that is very interesting on account of its ornamentation. Towards the north, in Nyasaland, cretaceous rocks are represented chiefly by sandstones, some conglomerates and limestones.

Tertiary and Recent.

Approximately one-third of the Province is covered by Tertiary rocks and Recent deposits.

During Tertiary times, some basalts, phonolites and other alkaline rocks, were intruded in sediments previously formed, and outcrop in Mossuril Bay, in Sena, in Cheringoma, Pessene near Lourenco Marques, and in other places. These Pessene rocks, as well as the basalt outcrop of

Little Lebombo, are younger than the conglomerates of Lourenco Marques and are probably post-lower Cretaceous to Tertiary. These lavas are very similar in composition to basalts of the Stormberg Series and to the Tertiary basalts of Mocambique district. These intrusions seem to be connected, to a certain extent, with the Great Rift Valley faults.

In the south of the Province, the sedimentary Tertiary rocks outcrop only in small patches through more recent deposits, but to the north, in the Buzi and Cheringoma regions, there are some tertiary nummulitic limestones, while towards Chentoby, in the Sena district, the limestone rocks are lacustrine in origin and contain *Melania and Helix*.

The coast in the Mocambique district is also formed by tertiary limestone, having a basal conglomerate with pebbles of Cretaceous limestone and gneiss; the same kind of rock is found to the north in Nyasaland.

The Tertiary rocks of this Province belong to the Eocene and Miocene and some of the superficial deposits may also belong, in part, to the Pliocene, but as no fossils have been found, there is a very great difficulty in separating them from the Pleistocene deposits.

The superficial deposits are chiefly sands that cover the surface of a great part of the Lourenco Marques and Inhambane districts, the Buzi and Cheringoma regions and the lower Zambezi and its delta. In the river courses, there are alluvial deposits, very important in some of the largest. They consist chiefly of clay and pebbles and sometimes sands.

Where the rivers lie on the old archaean rocks the alluvium consists generally of reddish sands and very often contain gold. These alluvial gold deposits occur chiefly where there are rocks of the primitive systems and granites, and near their contact; alluvial gold is more abundant in the regions of Macequece and Tete, but some has also been found in Nyasaland.

On the coast, sands, mostly white, very often form dunes, e.g. from Lourenco Marques to Cabo S. Sebastiao and also from Beira to the Zambezi delta. In the south they are fairly high and, by stopping the mouth of the rivers, produce a series of lagoons, as the Poelela, parallel to the coast. To the north of the Zambezi river, the coast is much more rocky and no dunes are found, but on the other hand, raised beaches are fairly common, some about 30 ft. above sea level.

Laterites occur very often, some pure, others with quartz sands and other impurities; in Mount Snuta, near the Manica frontier, some bauxite is found.

Near the coast, from Quelimane to Rovuma river, coral reefs are found in many islands close to the land.

Some human implements have been found, as well as pictures representing animals, in some of the more recent deposits and caves. Some of

those implements, very roughly manufactured, were found in the Mocambique district, and some neolithic ones in the Buzi river bed.

Thermal waters are fairly common in the archaean outcrops of the Province and they are found with temperatures ranging from about 40° to 70° centigrade, and occur in Manica and Sofala, Tete, and Quelimane districts and in other places. Most of them emit gas and some are sulphurous.

The Mocambique rocks were folded and faulted in different periods, by pressure and important movements of the earth's crust.

The first one known was produced during the old granite intrusions, when the rocks of the primitive systems were metamorphosed. During denudation of those systems, a new intrusion of granite and basic rocks formed some of the mountains, as the Gorongoza. After deposition of the Karroo and most of the Cretaceous rocks, a series of faults was produced that limited, more or less, the present Mocambique coast; some of the faulting continued well on into the Tertiary times and are connected with the movements that gave rise to the Great Rift Valley.

Before finishing this outline, it is necessary to say that after meeting Dr. Dixey at this Congress and discussing the Lupata Gorge geology with him, I found that the Lupata lavas half-way between Lupata Gorge and Port Herald, as stated by Andrew and Bailey, extend to Nyasaland.

The sketch map does not show it, as it was based, for this region, on Anthoine and Dubois on the Tete district.

61. APPLICATION NOUVELLE DES MÉTHODES DE LA POLARISATION SPONTANÉE A DES ÉTUDES TECTONIQUES.

PAR

P. CHARRIN.

Nous voudrions exposer une application à des recherches tectoniques de la méthode de prospection électrique connue sous le nom de méthodes de la polarisation spontanée.

Cette application n'est pas à proprement parler nouvelle, puisque la methode de la polarisation spontanée est utilisée dans ce but au KATANGA depuis plus de quatre ans; Par contre, aucune étude de ce genre n'ayant jamais fait l'objet d'aucune communication, nous espérons que le present exposé pourra presenter quelque interêt.

Nous regrettons que ces questions ne soient pas presentées ici par le professeur SCHLUMBERGER, professeur à l'école des Mines de Paris, qui depuis dix sept ans a tant contribué par ses travaux personnels à la mise au point et au developpement des methodes de prospection électrique, dont il a été le pionnier depuis 1911.

Parmi les nombreuses méthodes qu'il a mises au point, il en est une particuliérement bien connue sous le nom de méthode de la polarisation spontanée. Cette méthode a deja fait l'object de plusieurs publications, je me contenterai donc pour la clarté de l'exposé à en rappeler brievement les principes.

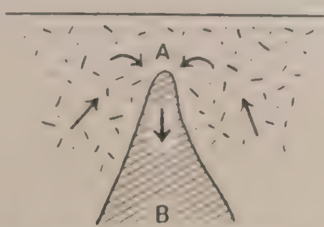
Les observations que l'on peut faire sur un amas conducteur enfoui dans le sol, un amas de pyrite par exemple, sont les suivantes. Effectuons des mesures avec ligne volante en circuit avec un galvanomètre et un potentiomètre et terminée par deux electrodes impolarisables. Quand on se rappoche du gisement, on commence à percevoir des différences de potentiel, l'electrode la plus voisine du gisement étant presque toujours negative par rapport à l'autre. La différence de potentiel ainsi observée va en augmentant à mesure que l'on avance et atteint son maximum quand on passe à l'applomb de l'amas.

Le résultat des mesures potentiometriques, que l'on effectue généralement le long d'un parcours rectiligne, se traduit commodément par un

profil des potentiels, sur lequel on porte les distances en abcisses et les potentiels en ordonnées. La présence du gisement se traduit sur le profil par un minimum négatif par rapport à la region neutre environnante.

Tel est le phenoméne, cherchons en l'explication.

On sait qu'en plongeant deux morceaux de minerai dans les deux compartiments d'un vase à cloison poreuse, on obtient un courant électrique dans la ligne qui les relie, pourvu que le liquide de l'un des deux compartiments soit oxydant.



Les phenomènes sont tout à fait analogues dans le sol, toujours plus ou moins humide; Une lentille de pyrite enfouie se comporte comme si elle etait plongée dans l'eau; la partie supérieure A est soumise à l'oxydation provoquée par les eaux superficielles relativement riches en oxygéne. La partie profonde B reste au contraire intacte. Sous l'action de cette dissymetrie chimique, le gisement forme pile et debite dans le sol un courant dirigé de B vers A et qui se ferme dans le minerai de A vers B. Le point A constitue donc un centre de potentiels negatifs, les differences de potentiel étant dues à la chute ohmique, qui resulte de la resistance du sol.

Pour qu'un gisement présente de la polarisation spontanée il faut:

Que le minerai soit métalliquement conducteur;

Que le gisement soit electriquement continu;

Qu'il y ait une dissymétrie sufficante entre le haut et le bas, ce qui sera realisé en particulier si la tète du gisement monte ou dessus du niveau hydrostatique.

En pratique, tous les amas de pyrite, presque tous les gisements sulfurés de cuivre et de plomb presentent de la polarisation spontanée.

Signalons aussi un fait que nous allons maintenant developper. Les anthracites, les schistes anthraciteux ou graphiteux donnent également une polarisation spontanée intense.

La présence et l'abondance de schistes graphite dans certaines régions minières (Province de Huelva en Espagne, de district de Sudbury au Canada, Rhodesie du Nord.) a toujours été considérée comme un des plus gros obstacles de la prospection électrique dans ces régions, en raison de la difficulté que l'on éprouve souvent à distinguer une reaction due à un véritable gisement de minerai conducteur d'une reaction due à des amas graphiteux sans aucune valeur.

Nous n'hésitons pourtant pas à dire que le graphite, considéré généralement comme le pire ennemi de la prospection électrique, peut être parfois un guide sur et précieux.

Peut être bousculons nous un peu les idées généralement admises à ce sujet. Cependant le succés de la méthode SCHLUMBERGER au KATANGA a été du en partie à la présence dans cette région d'horizons graphiteux.

Nous indiquerons maintenant les conditions particulières qui ont assuré ce succés.

Tous ceux qui ont fait du levé géologique en AFRIQUE CENTRALE, ou, d'une façon plus générale, dans les régions tropicales connaissent les difficultés qu'ils ont souvent rencontrées dans de vastes régions sans affleurements ou avec des affleurements trés dispersés, où tout est recouvert par un sol d'altération.

Dans certains cas, le levé géologique devient même complètement impossible à moins de creuser des tranchées, des puits de prospection, ou des sondages à main. Tous ces moyens sont extremement lents et couteux. Il n'y a donc rien de surprenant que dans ces conditions, au KATANGA, on ait fait appel à la prospection électrique, il y a déjà plus de quatre ans.

Trés vite on se rendit compte que l'échelle stratigraphique comportait plusieurs horizons graphiteux. On comprend que ces conditions aient souvent pu entraîner l'échec des méthodes qui utilisent uniquement la distorsion d'un champ électrique ou électro-magnétique. En effet, la distorsion du champ se produit sur les zones particulierement conductrices, qui sont souvent des zones particulierement graphiteuses et sans aucune valeur. L'horizon géologique en lui même n'est nullement caracterisé et ne peut être suivi que très difficilement.

Les méthodes de resistivités permettent au contraire de suivre des formations géologiques determinées, mais, dans le cas du KATANGA, nous avons pu nous contenter d'employer principalement, dans le même but, la méthode de polarisation spontanée, beaucoup plus simple et beaucoup plus rapide.

La possibilité d'application de cette méthode à l'étude géologique et tectonique des terrains au KATAGA, repose sur le fait qu'il existe deux horizons graphiteux très constants dans les formations géologiques.

Messieurs SCHUILING et TIMMERHANS donnent dans leurs communications le détail des connaissances actuelles sur la stratigraphie du KATANGA; je n'en dirai que quelques mots.

Tous les gisements de minerais oxydés et carbonatés du Katanga se trouvent dans une série géologique bien determinée applelée SÉRIE DES MINES, complexe de dolomies et de schistes dolomitiques.

Au dessus de cette première série, se trouve la série de N'GOYA ou de MUASHIA dont la partie supérieure se compose d'une forte épaisseur de schistes rubannés.

Au dessus enfin vient le GRAND CONGLOMÉRAT surmonté de toute la série des couches du KUNDELUNGU.

Dans tout ce système, nous disposons de deux horizons repères électriques remarquables.

Le plus élevé se trouve dans la série de MUASHIA un peu au dessous du Grand Conglomérat, c'est un horizon très constant de schistes noirs, souvent pyriteux, au milieu des schistes rubannés.

Le plus inférieur est un horizon graphiteux appartenant à la série des Mines elle même. Cet horizon graphiteux est généralement lié aux schistes dolomitiques, bien que ce ne soit pas une règle absolue. Il y a parfois deux horizons graphiteux, le deuxième appartenant aux calcaires ou dolomies supérieures de la série. D'ailleurs, suivant l'opinion de Monsieur SCHULLING, il est possible que les horizons graphiteux de la série des Mines aient joué un rôle important dans la réduction et la précipitation des solutions minéralisantes.

Dans ces deux horizons depères électriques que nous pouvons suivre très facilement, le premier nous sert à effectuer ou à préciser les études de tectonique générale, le second, encore plus important au point de vue pratique, nous sert à étudier en detail la série des Mines, determiner ses extensions et les principaux accidents transversaux qui l'affectent. Précisons ces deux points.

Le premier problème, qui se pose au KATANGA, est d'étudier la tectonique générale et en particulier de determiner le tracé des anticlinaux, au centre desquels on peut espérer trouver la série inférieure mineralisée, dite Série des Mines.

Pour ces premiers études générales, la prospection électrique est déjà d'un grand secours; en effet, l'horizon repère que l'on suit généralement géologiquement est l'horizon du grand conglomérat. Malheureusement, cet horizon est parfois caché par les recouvrements, comme c'est le cas par exemple dans toute la région de RUASHI et de L'ETOILE. La méthode de la polarisation spontanée permet alors de tracer d'une façon très précise les flancs des anticlinaux en suivant l'horizon graphiteux inférieur au grand conglomérat.

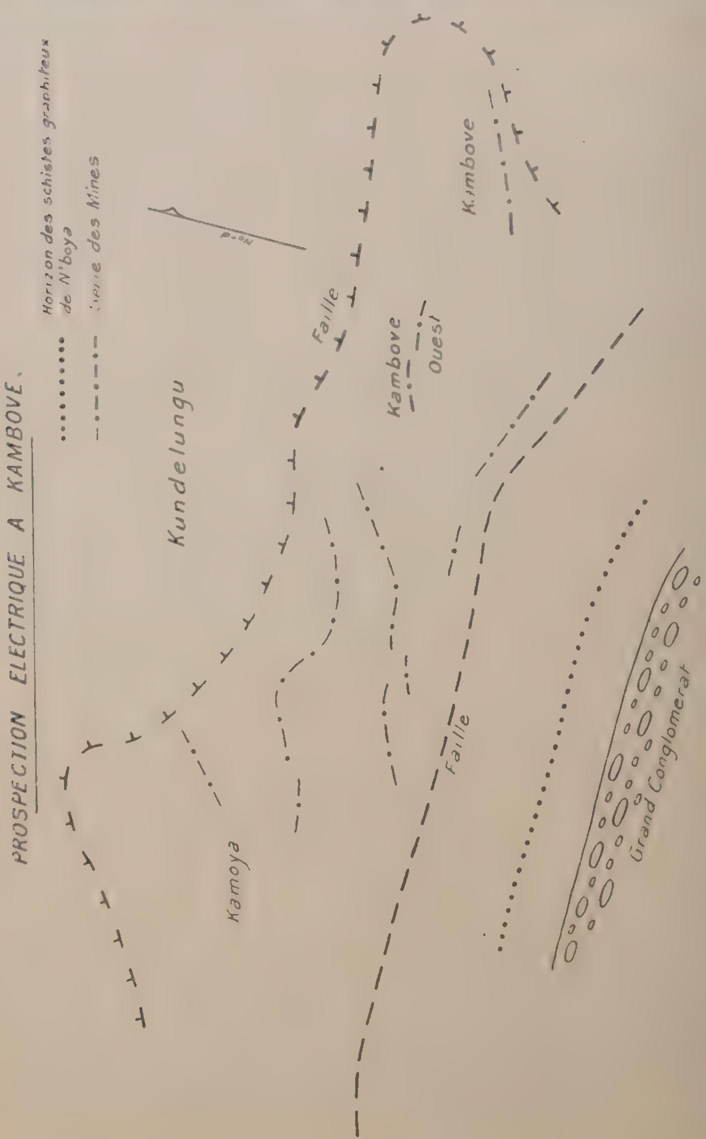
Même quand le Grand Conglomérat est visible, les indications électriques sont précieuses. En effet, l'horizon du Grand Conglomérat est épais (300 mètres au moins) et ne donne donc pas un tracé aussi précis que l'horizon très mince des schistes graphiteux qui lui est inférieur (2 ou 3 mètres).

Le second point, encore plus important au point de vue pratique et économique est l'étude de la série des Mines elle même. Les anticlinaux sont souvent très disloqués. Grace à l'horizon graphiteux de la série des Mines, les méthodes de polarisation spontanée nous permettent de repérer par des alignements de minima électriques les lambeaux de série des Mines, même masqués par un recouvrement important. Nous pouvons en outre determiner l'extension de ces lambeaux et voir, par l'interruption et les

rejets horizontaux de nos lignes de minima les zones qui sont affectées par des failles transversales, zones qui sont assez importantes en pratique.

Tout au moins en ce qui concerne les minérais oxydes, les méthodes électriques ne donnent pas d'indication sur la minéralisation ou la non-minéralisation de la série des Mines, mais il est evidement très important de pouvoir indiquer à priori les zones intéressantes à sonder.

Nous donnerons maintenant quelques exemples d'application pratique.



La carte ci joint de KAMBOVE montre les deux horizons repères dont nous avons parlé. Les schistes inférieurs au Grand Conglomérat dessinent le flanc sud de l'anticlinal, qui est trés regulier.

Plus au nord au contraire, tous les minima électriques appartiennent à la série des Mines. On voit que le tracé de ces minima a permis de suivre la série des Mines dans les régions sans affleurements et en particulier vers KAMOYA.

Ceux des membres du Congrés qui iront au KATANGA verront également un autre exemple de l'application de la méthode de polarisation spontanée à LUISHIA, où la série des Mines a été suivie sur plusieurs kilomètres sans affleurements. Plusieurs zones minéralisées ont été trouvées sur cet alignement, par les sondages qui ont suivi l'étude, la plus importante au point de vue économique étant le lambeau de série des Mines bien minéralisé au sud de la carrière de LUISHIA dans une zone où on n'avait aucune indication géologique.

Il est evident qu'au cours de ces études par procédés géophysiques, aucun indice géologique ne doit être négligé. Tout en effectuant les mesures électriques, les opérateurs relèvent tous les affleurements qu'ils peuvent trouver et l'interpretation s'appuie sur tous les faits géologiques connus. L'experience a demontré qu'un levé detail, effectué par mesures électriques et étude géologique simultanées, était plutôt plus rapide qu'un levé géologique seul. Ce fait est du, d'une part à ce que les mesures de polarisation spontanée sont extremement rapides et d'autre part à ce que les travaux de puits ou de tranchées destinés à identifier les formations géologiques sont réduits au minimum.

J'ajouterai enfin qu'une des raisons pour lesquelles la prospection électrique a reussi au KATANGA est que l'interprétation des résultats a toujours été effectuée par des géologues connaissant parfaitement la géologie du pays. Ils ont donc pu tirer de l'instrument nouveau qui était mis à leur disposition son rendement maximum.

Je crois que cette application nouvelle de la métode de la polarisation spontanée à l'étude d'un problème de tectonique générale méritait d'être signalée.

Je m'empresse d'ajouter d'ailleurs qu'il ne faut pas espérer généraliser ce genre d'application. Les problèmes de tectonique à resoudre par les méthodes électriques sont en général à traiter par les métodes de resistivités. La méthode de la polarisation spontanée reste surtout une methode d'investigation des minérais conducteurs et son application à la tectonique reste exceptionnelle.

Cependant les possibilités qu'offre cette méthode très rapide chaque fois que l'on a des horizons graphiteux réguliers ne doivent être perdues de vue.

62. ETAT DES CONNAISSANCES ACTUELLES SUR LA GÉOLOGIE DU MAROC

PAR

L. NELTNER.

Depuis bien longtemps les explorations de quelques géologues; LEMOINE, BRIVES et surtout GENTIL, ont fait connaitre les grands traits de la géologie du MAROC; mais ce n'est que depuis peu que l'on a commencé une étude détaillée et précise. Le premier LECOINTRE commença ce travail sous l'égide de l'Institut scientifique chérifien mais c'est au Service de la carte géologique que l'on doit la plupart des résultats acquis actuellement. Grace à l'heureuse et énergique initiative de M. l'inspecteur général LANTENOIS de nombreux géologues sont venus travailler pour ce service: MM. DAGUIN, BOURCART (également géologue de l'Institut scientifique), LACOSTE L. MORET, E. ROCH, H. TERMIER et moi-même. C'est à l'exposé volontairement très objectif des résultats de ces dernières années que je désire consacrer ces quelques pages. Les principales découvertes récentes portent sur le Rif, la meseta marocaine, le Haut Atlas et les confins sahariens; nous allons les passer en revue successivement.

LE RIF. Resté innaccessible jusqu'a ces dernières années le Rif commence à être un peu connu. Au dernier congrès DAGUIN a exposé ses résultats et indiqué l'existence d'une nappe, la nappe trias nummilitique ou nappe du Sebou. Le docteur RUSSO qui a parcouru rapidement la chaine donne à ce congrès une note sur ses travaux, je me bornerai donc ici à parler des études détaillées de Bourcart et Lacoste.

Ils ont d'abord fait une étude minutieuse de la stratigraphie, étude qui conduit à rapporter au crétacé la plupart des schistes métamorphiques jadis rapportés au primaire; ce dernier n'est guère représenté que par de rares schistes cristallins. Malgré les difficultés rencontrées dans un pays marneux où les interprétations reposent souvent sur la distinction entre les marnes et argiles du crétacé et du Vindobonien, on commence à voir clair.

Dans les Djebalas (J. Bourcart) on distingue 2 entités poussées sur l'autochtone formé de primaire de Trias argilo salin de lias, d'éocrétacé, ce sont:—

1) Une entité essentielement formée de lias et de nummulitique, qui n'est autre que le prolongement de la nappe de Sebou. Essentiellement formée de calcaires liasiques, de calcaires, marnes et grès nummulitiques cette série est souvent triasifiée à la base, mais contrairement à Daguin J. Bourcart considère ce trias comme d'origine autochtone.

2) Une entité formée d'Eocrétcé et de nummulitique.

Cette série comprend des calcaires et du flysch calcaire eocrétacés et des grès nummulitiques souvent continentaux.

Ces 2 séries sont poussées vers le Sud ouest.

La série 2 enracinée vers Chechaouen constitue la presque totalité du massif montagneux compris entre El Ksar, Tanger, Tétouan et Chechaouen.

La série 1 enraicinée vers Ceuta a largement chevauché cette première nappe puis l'autochtone en avant de celle ci; elle s'étendrait au Sud jusque vers Souk el Arba du Gharb (cela est discuté) et irait vers l'Est rejoindre la nappe du Sebou.

Ces séries forment des lames (nappes du type dinarique, nappes cassantes d'E.Argand) charriées les unes sur les autres vers l'extérieur de l'arc riffain.

Tout cet ensemble a été mis en place en 2 temps:

un premier plissement post priabonien a produit le déferlement des nappes;

un second plissement post astién qui a replissé énergiquement les lames charriées et l'autochtoné.

Ce dernier plissement d'un type très special a déterminé des cuvettes synclinales très courtes (que l'érosion laisse en relief) entourées de mailles anticlinales profondément érodées; ces anticlinaux sont très aigus du type diapyre. Vers l'Est ce style s'estompe et à partir de Ain Defali on a des plis courts mais parfaitement linéaires.

Plus à l'Est dans la région au sud de l'Ouergha, J. Lacoste a mis en évidence la présence de la nappe du Sebou, mais ici la nappe contient du lias qui n'existait pas au sud dans la région étudiée par F. Daguin Elle correspond sans doute à la nappe des Djebalas.

Aux abords immédiats de l'Ouergha et au nord de cette rivière on rencontre 2 lignes parallèles de pitons liasiques orientées a peu près S.E.-N.O et à convexité en général tournée vers le S.O. Ces lignes sont fréquemment défunies par des klippes d'origine voisine: ils proviennent des massifs plus importants qui sont des plis couchés liasiques à auréole très souvent méta morphique où apparaissent parfois le lias supérieur et le Jurassique et toujours le crétacé. Le mouvement des plis couchés et leur deversement se fait toujours vers le nord et ainsi les rides les plus méridionales limitent en

les coiffant parfois les terrains de la nappe du Sebou. Ces rides liasiques à peu près parallèles escortées de dépots profonds métamorphiques viennent confirmer géologiquement le nom géographique de Cordilière maintes fois appliqué au Rif.

Meseta Marocaine. Les affleurements primaires se répartissent en 2 zones séparées par le plateau crétacé éocène d'Ouezzem, le plateau des phosphates.

Au Sud de ce plateau le silurien et le cambrien moyen à trilobites et archæocyathus ont une grande extension, le silurien flanquant très régulièrement à l'Est les couches cambriennes.

Au nord de ce plateau une immense zone primaire allant de la côte au Moyen Atlas forme le Maroc central. La partie voisine de la côte a fait l'objet d'un travail déjà publié de Lecontre qui y a rencontré les divers niveaux primaires plissés en direction N.S. Un peu à l'Est vers Tiflet j'ai trouvé le dévonien supérieur et le carbonifère plissés en direction E.O. supportant quelques petits lambeaux de recouvrement de Gothlandien.

Mais la plus grande partie de la région a fait l'objet des études de H. Termier qui en a établi une minutieuse stratigraphie comportant tous les niveaux importants de l'ordovicien au viséen.

Au centre on trouve un vaste bombement silurien comprenant l'ordovicien (très épais, 2000 m.) à Trinucléus entre Christian et Oulmès et le gothlandien (schistes à graptolites et à Cardiola interrupta et quartzites); Un synclinal secondaire dans ce silurien montre le dévonien inférieur (gédinnien à faune de Konieprus à 7 k. au sud de Tedders) et moyen (Givélien aux environs d'Oulmès).

A l'ouest une longue bande dévonienne flanque ce silurien (grauwacke coblentzienne à Spirifer cultrijugatus, calcaires marneux de l'Eifélien riches en goniatites, trilobites et lammellibranches qui l'apparentent à la Bohème).

Cet ensemble est entouré par une immense étendue (7000 km.^{2}) de calcaires schistes et grauwackes viséennes où les faunes permettent de reconnaitre 2 zones: le viséen inférieur, (très important à l'ouest vers Kasbah ben Ahmed entre l'oued Zemrane et le djebel Mtiret) et le viséen supérieur qui couvre le pays zaian et s'étend chez les Beni m'Tirs à l'ouest d'Azrou et chez les Zemmours au sud de Khemisset.

De petits anticlinaux font apparaître des terrains plus anciens à travers ce viséen supérieur: on trouve ainsi une longue bande gothlandienne entre Khenifra et Azrou et divers pointements dévoniens (Eifélien à goniatites à Dechra ait Abdallah près d'El Hamman, Givétien près d'El Hamman également, Frasnien à Mrirt, Fammennien entre Khenifra et Aguelmous, ces 2 derniers étages avec une admirable faune de Goniatites).

Au sud de cette zone primaire le crétacé repose directement sur le primaire tandis que sur ces autres faces le primaire est bordé de permo trias

rouge qui le sépare du lias depuis Khenifra jusqu'à Sefrou et du miocène de Marchand à Bataille. Vers Khenifra une plante assez mal conservée permet d'établir la présence de permien bien défini.

Entre notre massif primaire et le Moyen Atlas s'étend le causse pré atlasique formé de calcaires massifs du lias moyen (pliensbackien sans doute).

Trois grandes ellipses granitiques d'âge probablement hercynien sont venues se loger dans ces sédiments; ce sont celles de Christian d'Oulmés et d'Aguelmous; de nombreux filons de micro granites et de dolérites recoupent les couches.

Tous les terrains primaires ont été plissés fortement avant le dépot du permo-trias; ces plis sont parfois aigus mais nulle part ici on ne trouve d'indices de charriages. Il est probable que des mouvements posthumes, post autuniens mais antétriasiques ont affecté la région de Khénifra.

Le Moyen Atlas. L'étude stratigraphique détaillée a montré la présence de calcaires et marnes du lias et du dogger recouverts vers Bekrit par le cénomanien transgressif. Le crétacé supérieur trouvé vers Timhadit est le terrain le plus récent affecté par le plissement tertiaire; le premier dépot posterieur au plissement étant le Miocène à Ostrea crassissima l'âge du plissement reste encore largement indéterminé. Le style tectonique est caractérisé par de larges régions synclinales séparées par des anticlinaux tigus s'éxagérant parfois jusqu'au pli faille.

Le Haut Atlas et sa Bordure. Le Haut Atlas peut être commodémment divisé en 3 tronçons:

(1) *le massif secondaire de l'ouest* surtout formé de crétacé allant de la mer à l'oued Ait Moussi;

(2) *le massif central du Haut Atlas*, primaire, s'étend jusqu'au col de Telouet;

(3) *le massif secondaire de l'Est* surtout jurassique, qui s'étend jusqu'au Sud algérien.

De ce dernier massif nous ne pouvons rien dire de nouveau car il est presque entièrement dissident. Il semble toutefois que l'on y retrouve encore l'allure particulière des anticlinaux se relavant décrite il y a longtemps déja dans les confins algéro marocains. Nous traiterons un peu en détail les 2 autres tronçons.

1) *Massif secondaire de l'ouest et zone littorale*. Ils ons été l'objet de minutieuses études stratigraphiques de la part de E. Roch, qui y a découvert un jurassique rouge subcontinental qui représente le lias et le dogger déposés en bordure du massif central émergé du Haut Atlas. Une belle faune du jurassique du crétacé et de l'éocène ont permis à Roch une belle synthèse paléogéographique que j'exposerai ici d'après cet auteur

Les facies du jurassique se font de plus en plus littoraux au fur et à mesure que l'on s'avance vers l'Est à proximité du massif central émergé du Haut Atlas.

Pour le crétacé on voit avec une admirable netteté les facies pélagiques à Phylloceras, Lytoceras, Crioceras développés vers la côte (fosse des Haha) devenir de plus en plus littoraux vers l'intérieur des terres et passer à des formations rouges et détritiques de facies subcontinentaux ou tout au moins lagunaires.

On peut suivre le détail de ces transformations et résumer ainsi qu'il suit le jeu des transgressions et des régressions.

La transgression débute au Callovo Oxfordien, elle se poursuit durant le reste du Jurassique et tout le Néocomien date à laquelle la mer s'est engagée dans le sillon subatlasique scindant le bloc Djebilet Haut Atlas. Mais il ne se dépose là que des sédiments détritiques et rutilants peu fossilifères accompagnés de bancs de gypse. Le retour momentané à des facies franchement marins dans le sillon subatlasique ne se fait que dans les couches de passage de l'Aptien à l'Albien (niveau de Clansayes).

Après une période qui correspond au Cénomanien au Turonien (?) et au Sénonien inférieur, et où reviennent dans ces régions les facies détritiques et les influences continentales, la transgression reprend au Maestrichtien, époque à laquelle se fait une avancée notable de la mer, et se poursuivra, beaucoup plus grandiose d'ailleurs à l'Eonummulitique:—

Le Néonummulitique, et aussi vraisemblablement le néogène inférieur seraient représentés sans doute dans le complexe de marnes et de grès rouges décrits sous le nom d'Aquitanien par Savornin. C'est un dépot continental de démantèlement de la chaine atlasique en voie de surrection, on ne sait pas au juste jusqu'où la mer était rejetée à cette époque. Peut être cependant le miocène est il représenté en bordure du littoral par une partie des grès dunaires à Ostrea (du groupe de l'ostrea gingensis);

Il est impossible de fixer exactement la date du début des plissements tertiaires car les couches qui surmontent en concordance l'Eonummulitique sont absolument dépourvues de fossiles. Les plissements se manifestent en tout cas jusqu'à une époque très récente car le pliocène (ou le quaternaire) a été en certains points soulevé jusqu'à une altitude de plus de 500 mètres

L. Moret a retrouvé des résultats analogues dans son étude de la bordure crétacée au nord et au sud du massif central du haut Atlas.

2) *Le massif central du Haut Atlas* apparait comme essentiellement formé par un gros paquet de cambrien flanqué à l'ouest et à l'est de sédiments primaires plus récents; Ce cambrien (L. Moret, L. Neltner) montre une énorme épaisseur (1000 à 2000 m. au moins) de calcaires à Archaeocyathus, de grès à Ellipsocephalus et de schistes à Paradoxides et Olenoides: A l'ouest il est bordé de dévonien et de schistes siluriens où Roch a trouvé

Placoparia Zippei et *Stropheodonta tenuissimestriata*. A ses extremités le massif cambrien est bordé de carbonifère schisteux: Dinantien, Westphalien à l'Est, Stephanien (ROCH) à l'Ouest. Le Permo trias est représenté par une énorme masse de grès et argiles rouges où l'absence de fossiles rend impossible toute séparation plus précise. ROCH a d'ailleurs montré qu'une partie du Stéphanien pouvait entrer dans la composition de ce facies compréhensif:—

Immédiatement au sud de Marrakech se dresse la partie la plus haute de la chaine essentiellement constituée de granites, diorites, andésites

Ce granite n'est pas un produit de métamorphisme régional car il n'a point d'auréole de gneiss et de micaschistes; il est intrusif dans le cambrien. Postérieurement une venue andésitique (dont les cheminées très nettes traversent le granite) est venue se loger en lacolithe entre ce granite et le cambrien. Les relations exactes de ces roches et des terrains avoisinants sont encore imparfaitement connues, de même l'age de leur mise en place.

Dans ce massif primaire il n'y a pas trace de mouvements calédoniens; E. ROCH y signale la possiblité d'un mouvement huronien mais les phases certaines d'orogénèse sont la phase hercynienne et le phase alpine.

Le plissement hercynien est ici antestéphanien car le stéphanien repose en discordance sur le primaire ancien (E. ROCH); on sait d'autre part qu'il est post dinantien. Le plissement de direction N.N.E. affecte très vivement le primaire dans la partie ouest mais s'estompe graduellement dant la partie orientale si bien que vers l'Ourika on voit le carbonifère reposer en concordance sous le permo trias.

Le plissement alpin est simple sans mouvements tangentiels considérables. Les plis de direction E.N.E. sont souvent serrés et déversés vers l'extérieur de la chaine. Quelques synclinaux pincés, un décollement local à la base du permo trias et surtout les grandes failles bordières sont les accidents les plus saillants.

LE BORD DU BORCLIER SAHARIEN: ANTI ATLAS: PLATEAUX DU DRAA ET AU TAFILALET. L'Anti atlas se présente (L. GENTIL) comme un immensé anticlinal de fond bordé au sud par le vaste synclinal de Tindouf, où Menchikof a trouvé une magnifique série dévonienne et carbonifère. Les couches de l'Anti atlas se rattachent au cambrien et au précambrien. Le facies le plus constant est un calcaire dolomitique à lentilles et bancs de silex qui forme le sommet de la série. Les *Archaeocyathus* trouvés par J. BOURCART vers Tiznit, retrouvés par moi vers Tiout et la parfaite continuité des ces couches avec le cambrien du Haut Atlas établissent indiscutablement leur âge. Sous ces calcaires repose une série détritique à facies très variable (quartzites, pouddingues à galets de quartzites, de quartz et roches éruptives passant par endroits à de véritables arkoses). Vers l'Est le plissement de l'Anti Atlas s'atténue et l'on passe aux plateaux du Draa où cette série cam-

brienne est en moyenne horizontale, affectée seulement de plissotements locaux. En discordance complète sous celle ci j'ai observé à Tazenakht des gneiss et micaschistes verticaux qui forment le substratum arasé de la plaine des Zenaga. Ces gneiss et micaschistes sont ainsi le premier précambrien certain connu en Afrique.

Le primaire se continue vers l'Est et forme le Djebel Sagho jusqu'ici attribué à tort au crétacé et ainsi à travers la zone insoumise l'on atteint le Tafilalet. Entre cette palmeraie et la bordure de la Hammada apparait une belle série comprenant le dinantien le dévonien (dévonien supérieur principalement) et l'ordivicien à Trinucleus. Ces couches légérement plissées en direction E.O. vont s'enfoncer sous les couches crétacées et tertiaires horizontales de la hammada.

63. ORIGINE DELLE DEPRESSIONI CHIUSE DELLA REGIONE DEL GOLFO DI SAN GIORGIO (PATAGONIA.)

PER

EGIDIO FERUGLIO.

Cenni generali. — L'altipiano della Patagonia é disseminato di numerose depressioni chiuse, ora isolate, ora riunite in gruppi o disposte in allineamenti. Varia ne é la grandezza, da piccole conche di alcune decine di metri di diametro e pochi metri di profonditá, a depressoni con un diametro di alcuni chilometri e fortemente incavate. Alcune hanno fondo piatto ed altre irregolare, recinto da pareti a dolce pendio o fortemente inclinate. Molte ricettano sul fondo una o più raccolte d'acqua; stante però l'aridità del clima (da 100 a 300 mm. annui di pioggia), questi stagni a volte si prosciugano durante la stagione secca e ventosa (estate), depositando sul fondo uno strato salino, di spessore e composizione variabile. Le conche ricevono il nome di *lagunas* se occupate da uno stagno permanente o no, e di *salitrales* se normalmente asciutte e coperte da una crosta salina, essendo paragonabili agli *shotts* tunisini e alle sebkhe del Sahara.

L'origine di queste conche fu diversamente interpretata dagli autori, gli uni (FOUROUS, KEIDEL, WICHMANN) considerandole dovute principalmente all'azione degli agenti esterni e sopratutto del vento, gli altri (F. AMEGHINO, ROVERETO e WINDHAUSEN) prodotte da sprofondamenti tettonici, ovvero (ROVERETO e KEIDEL) dall'azione concomitante delle forze endogene (piegamenti e sprofondamenti tettonici) e degli agenti della degradazione (specialmente del vento) (1).

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(1) ROVERETO fu il primo ad accertare e a descrivere in Patagonia delle conche di sprofondamento tettonico "Rendiconti della R. Accademia dei Lincei," vol XXIII, 1 semestre, 1913.—*Studi di Geomorfologia argentina V. La penisola Valdez*; Boll Società Geologica Italiana, vol XL (1921).—*Trattato di geologia morfologica*. Milano, 1923-1924, vol I, pag 301, vol II, pag 948 e 1000.—KEIDEL, *Ueber das patagonische Tafelland* ecc., Zeitschr Deutsch Wissenschaftl Vereins Buenos Aires, 1917 e 1918.—WINDHAUSEN, *Rasgos de la historia geologica de la planicie costanera en la Patagonia Septentrional* Boletin Acad Nac de Ciencias en Córdoba, XXIII (1918), pag 319.

Fig. 1.—Cartina della regione del Golfo di San Giorgio.

Io ho studiato queste depressioni nella porzione d'altpiano che s'inarca intorno al Golfo di San Giorgio (Fig. 1); però l'uniformitá delle condizioni geologiche, strutturali e climatiche della Patagonia, dá un valore piú generale alle mie conclusioni, che sono basate sempre su osservazioni particolareggiate.

I piú antichi terreni affioranti nella regione del Golfo di San Giorgio sono costituiti da colate di porfido quarzifero, intercalate a tufi e riferite al Triasico superiore. Queste rocce affiorano a poca altezza sull'oceano nei due aggetti di Camarones e Bustamante, e di Puerto Mazaredo e Puerto Deseado, che limitano a N e a S il golfo. In corrispondenza alla rientranza del golfo, si deprime un ampio bacino, riempito da una serie di sedimenti alternatamente continentali e marini e compresi cronologicamente fra il Cretaceo inferiore e il Quaternario. La serie s'inizia inferiormente con un potente complesso (fina a 2.000 m. di spessore) fluviale e fluvio-lacustre a

resti di Dinosauri e legni silicizzati, distinto col nome di *Chubutiano*. Nella parte superiore di questo complesso s'intercala una formazione marina, argilloso-arenacea (*Salamanchiano*), riferita al Senoniano superiore, con spessore decrescente dalla costa verso l'interno, dove viene sostituita da depositi terrestri. Sopra il Salamanchiano si adagia in concordanza un nuovo complesso terrestre argilloso-arenaceo, a resti di Dinosauri e legni silicizzati, che riceve il nome di *Pehuenche* e riferito al Daniano. Il Terziario s'inizia con tufi cineritici, potenti fino a 160 m., a resti di Mammiferi e che comprendono l'Eocene e forse parte dell'Oligocene. Su questi tufi, o direttamente sui terreni piú antichi, si adagia in trasgressione il complesso marino Patagoniano-Entrerriano (Oligocene e Miocene) potente fino a 400 m. e costituito da sedimenti arenacei e argilloso-turfacei, ricchi di avanzi fossili e con interposti banchi resistenti ad ostree. Copre questo complesso una serie di arenarie terrestri a stratificazione incrociata (150-200 m. di spessore), riferita all'Araucaniano (Pliocene.)

Nell'altipiano gli strati giacciono d'ordinario orizzontali o poco inclinati, con pieghe a dolce curvatura e intersecate da faglie di vario rigetto e diversamente orientate (spesso scaglionate in serie parallele.) La struttura tabulare si riflette direttamente sulle forme del rilievo, che é caratterizzato da una successione di ripiani piú o meno estesi e frastagliati, che si elevano a gradini dall'oceano, culminando a poca distanza dalla costa nell'altipiano della Pampa de Castillo (600-800 m. d'altitudine), disteso in stretta fascia intorno al golfo, e che declinano nuovamente a ripiani (*mesetas*) verso l'interno, ad un'altitudine di 500-600 m. In mezzo all'altipiano a struttura tabulare, fra i meridiani 69° e 70°, sorge un sistema di monti a pieghe (Sierra de San Bernardo, Sierra del Castillo ecc.), piuttosto compresse e in parte rovesciate, dirette da S a N in coincidenza con le dorsali orografiche. Al piede orientale di questo sistema oro-tettonico, si stende la Cuenca de Sarmiento, occupata nella sua parte settentrionale dai laghi Musters e Coli Huápi e che é la depressione piú vasta dell'altipiano patagonico.

La regione é stata soggetta durante il Terziario a vari movimenti successivi, che iniziatisi nell'Eocene (la fase diastrofica terziaria), si ripeterono nel Miocene (2.ª fase) e nel Pliocene (3.ª fase.) La prima fase produsse il corrugamento della Sierra de San Bernardo e sollevó, fratturando in parte, la regione tabulare ad [illegible]rale. Questa fase é stata accompagnata e seguita dall'intrusione ed effusione di rocce alcaline basiche, distribuite sopratutto ai due lati della conca attuale di Sarmiento. I movimenti della terza fase, svoltisi a piú riprese durante il Pliocene e continuatisi poi nel Quaternario, accentuarono le pieghe della Sierra de San Bernardo e quelle

ad esse laterali e causarono un sollevamento generale di tutta la regione, con l'apertura di numerose faglie. Da questo sollevamento conseguí un graduale approfondimento della rete idrografica, segnato da una successione di 3 terrazzi principali nell'interno, cui corrispondono 3 o 4 principali terrazzi marini lungo la costa. L'ultima fase diastrofica é stata accompagnata dallo sgorgo di vasti espandimenti di lave basiche, estesi specialmente nella Sierra de San Bernardo e nella regione limitrofa ([1]).

Depressioni chiuse dovute a sprofondamento tettonico.—Le depressioni chiuse della regione in esame si possono raggruppare, riguardo alla loro genesi, in tre categorie principali. Um primo gruppo di depressioni trae origine da cause tettoniche, e cioé dallo sprofondamento di zolle piú o meno estese di suolo limitate da faglie perimetrali o diversamente disposte. A questa categoria appartengono d'ordinario le depressioni piú estese e profonde della regione studiata, pur avendosene di forma e dimensioni svariatissime. Un'origine tettonica ho potuto accertare per alcune delle conche che costellano l'altipiano situato a ponente della Sierra del Castillo, ed è evidente in ispecial modo per la depressione detta Gran Bajo de Buen Jasto, aperta in una regione a struttura tabulare, con pieghe a curvatura dolcissima. Nel margine orientale conca della (fig. 2), gli strati terrestri del Cretaceo superiore, attraversati da numerosi filoni-strati d'una roccia basica, si abbassano improvvisamente a guisa di flessura, presentandosi rotti da numerose faglie. La conca sembra coincidere con la vólta sprofondata di un'ampia e dolce anticlinale.

Eguale origine spetta sicuramente ad una parte almeno delle numerose conche che si aprono nei dintorni e distribuite senza alcun ordine apparente. Lungo il margine di alcune di queste depressioni osservai chiari indizi di rottura e sprofondamento degli strati, e spostamenti di blocchi limitati da faglie. Le faglie peró sono raramente visibili e seguibili in superficie, a causa del detrito roccioso e della sabbia eolica che copre il suolo, potendosene dedurre l'esistenza dal salto e spostamento degli strati. L'altipiano é letteralmente cribrato di depressioni chiuse, da poche centinaia di metri a vari chilometri di diametro, e che gli dánno l'aspetto di una regione a crateri.

([1]) Per la storia geologica della regione del Golfo di San Giorgio si consulti i miei due lavori recenti: *Costituzione geologica della regione del Golfo di San Giorgio (Patagonia)*, Boll. Soc. Geol. Ital., vol. XLVII, 1929, fasc. 2; *Apuntes sobre la constitución geológica de la región del Golfo de San Jorge*, Anales Sociedad Argentina de Estudios Geográficos "Gaea," 1929.

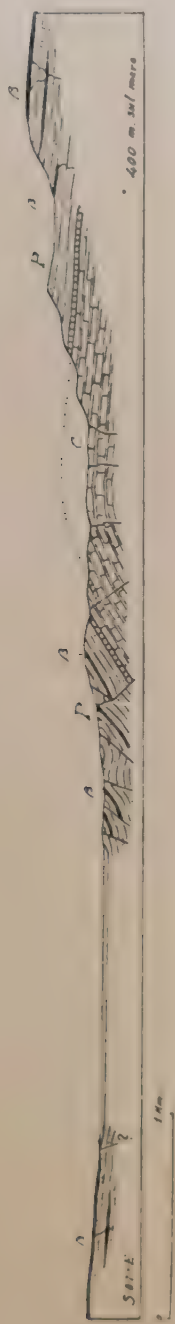


Fig. 2.—Sezione della depressione di Buen Pasto.—C, Chubutiano; P, Pehuenche; B, rocce eruttive basiche

Le condizioni geologiche dell'altipiano escludono l'ipotesi di un'origine collegata con esplosioni vulcaniche. Le rocce magmatiche distribuite nei dintorni sono anteriori alla formazione delle conche e furono eruttate nel Miocene o Pliocene e successivamente dislocate dai movimenti tettonici. Gli espandimenti lavici si presentano curvati ad ampie sinclinali ed anticlinali, che siriflettono nel substrato sedimentario (¹).

Notevole per la frequenza delle depressioni chiuse é l'ampia terrazza che si stende nell'estremitá meridionale della regione del Golfo di San Giorgio, fra Puerto Deseado e Puerto Mazaredo. La terrazza si eleva dall' oceano a gradini o con una scarpata unica, raggiungendo un'altitudine di 100-200 m. Sopra un substrato costituito da porfidi e tufi d'etá triasica, si stendono dapprima sedimenti argillosi e tufacei del Cretaceo superiore e tufi cineritici a resti di Mammiferi (Eocene), sopra cui si adagiano trasgressivamente i sedimenti marini del Patagoniano inferiore, disposti in istrati suborizzontali e qua e lá dislocati da piccole faglie. La superficie piana della terrazza taglia, nel complesso, obliquamente gli strati e corrisponde ad una superficie di abrasione marina, d'etá pliocenica: essa é coperta da un manto di sabbia e ghiaia, contenente a luoghi resti di molluschi di specie viventi ed estinte (*Laziarense.*) Su questa superficie si aprono numerose conche, con diametro variabile da poche decine di metri a qualche chilometro e con profonditá massime di 60—80 m., recinte da pareti a dolce declivio e piú spesso ripide o tagliate a scarpata. L'origine tettonica di almeno una parte di queste conche é dimostrata, oltre che dalla loro orientazione e distribuzione, che é indipendente rispetto alla direzione del vento dominante, dall'evidente rapporto con faglie accertato per alcune di esse e dall'esistenza di piccoli campi di faglie scaglionate lungo la costa e connessi con sprofondamenti del suolo. Riguardo alla distribuzione delle conche, é da notare che a volte si presentano disposte in serie, in numero vario (fino a 7 sopra una lunghezza di 25 km.) essendovi due allineamenti principali, l'uno diretto E-W od WNW-ESE e l'altro N-S. In correlazione con questo fatto, é notevole la circostanza che queste due linee direttrici (corrispondenti se non a linee continue di faglia, almeno a zone di minore resistenza e di piú facile fratturazione) decorrono parallelamente ai due tratti di costa che delimitano l'aggetto subquadrangolare che chiude a S il

(¹) Con ció non si vuole escludere il concorso inderetto dei fenomeni vulcanici, nel senso che l'espulsione di grandi masse laviche possa avere determinato degli squilibri nelle masse rocciose, provocando movimenti di assestamento e avvallamenti del suolo.

Golfo di San Giorgio, e il cui tracciato probabilmente é stato determinato in parta da cause tettoniche.

L'etaá di queste conche tettoniche si puó desumere dal fatto che in gran parte si trovano impostate sopra una terrazza marina d'etá pliocenica e alcune di esse sopra una terrazza inferiore, presumibilmente quaternaria antica. Le conche situate a ponente della Sierra del Castillo, si sono formate probabilmente in séguito agli ultimi movimenti della 3a. fase (Pliocene e Quaternario inferiore).

Depressioni di escavazione eolica.—Nell'altipiano patagonico il vento é tra le cause denudatrici più notevoli e forse preponderante. Dal clima arido e ventoso che caratterizza la regione, consegue una notevole povertá nel rivestimento vegetale. Quest'ultimo é costituito in gran parte da piante erbacee, che non formano un tappeto continuo e uniforme, ma crescono in cespi isolati (Graminacee ed Ombrellifere), o in densi e compatti cuscini (*Azorella* ecc.), intramezzati, dove piú e dove meno abbondantemente, da cespugli ed arbusti di piante in parte spinose. Le aree coperte di vegetazione alternano con tratti di suolo nudi o quasi spogli di vegetazione, costituiti quali da rocce sedimentarie e laviche dure e compatte, quali da sedimenti argillosi, arenacei e tufacei fini, nel qual caso si presentano dilavati, solcati e finemente cesellati dalle acque di scorrimento superficiale, che dánno al paesaggio l'aspetto d'un *bad land*.

Il vento spira ordinariamente dall'altipiano verso l'Atlantico ed é particolarmente insistente e impetuoso durante la primavera e l'estate, assumendo a volte la forza d'un uragano (oltre 100 km. all'ora.) La sua azione degradatrice é favorita (come sempre avviene nelle regioni desertiche e subdesertiche) dalla rapida disgrezione delle rocce, conseguente all'ariditá del clima, alle forti variazioni termiche e alla discontinuitá del tappeto vegetale. Esso solleva e trascina quantitá ingenti di fino detrito roccioso, che finisce col depositare in seno all'oceano. L'azione abrasiva del vento é naturalmente piú intensa nei terreni friabili, ridotti superficialmente incoerenti dalla disgregazione e dalla siccitá. La sua efficacia in Patagonia é aumentata dalla grande distribuzione che vi hanno i terreni argilloso-arenacei e tufacei fini del Cretaceo superiore e del Terziario (1).

(1) L'erosione del vento é evidente nelle valli che solcano il versante costiero dell'altipiano e che vengono prese d'infilata e violentemente spazzate dalle correnti aeree che stramazzano dall'altipiano. Queste valli, solo raramente percorse da un rivolo d'acqua, hanno fondo piatto e dolcemente inclinato. La loro incisione é dovuta alle acque correnti, peró il vento le approfondisce e le amplia, dando loro un profilo longitudinale dolce e continuo e un profilo transversale ad *U* (determinato dalla presenza di banchi resistenti che sporgono orizzontalmente sul fianco della valle). Iil fondo delle valli é costituito da un potente strato di sabbia eolica rimaneggiata dalle acque. Al loro sbocco nell'oceano, per lo più ampio, si stendono accumulamenti di sabbia che vengono via via spazzati e nuovamente ricostituiti dal vento.

Sulla superficie dei ripiani e sul fondo delle valli, si aprono delle depressioni di varia grandezza, di solito a dolce invacatura e a pareti non fortemente inclimate. Il profilo di queste conche é in generale a piatto o a scodella. Il contorno puó essere irregolare, ma d'ordinario é ovale od ellittico, con l'asse maggiore orientato nella direzione del vento dominante. L'origine di queste conche é connessa col persistente soffiare del vento in

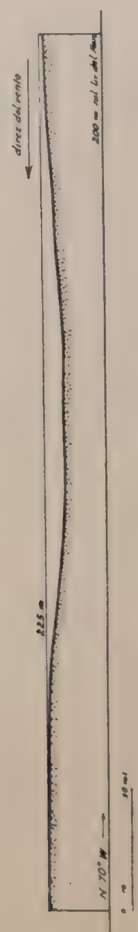


Fig. 3.—Profilo longitudinale di una conca di escavazione eolica.

una data direzione: in molte di esse si puó tuttora assistere al loro sviluppo. Ció avviene quando il vento vi si rovescia turbinando e sollevando un nembo di polvere e sabbia che travolge veloce dinanzi a sé. Sul davanti di queste conche, dalla parte opposta alla provenienza del vento, spesso si notano accumulamenti di sabbia, che si arrestano contro gli ostacoli del terreno e intorno alle piante e che possono sbarrare e recingere parzialmente la depressione. In tempo di pioggia le conche vengono allagate: l'azione ritmica delle onde mosse dal vento, accumula sulla riva un argine di terra e ciottoli, alto

fino a 2—3 m., cosìche anche l'ondazione concorre all'escavazione e all' approfondimento della conca.

Depressioni di sbarramento.—Nel Golfo di San Giorgio la costa si alza generalmente a scarpata, formata dagli strati suborizontali del Cretaceo superiore e del Terziario, ed é interrotta per brevi tratti dalle ampie foci dei torrentelli, normalmente asciutti, che scendono dall'altipiano. Le foci si allargano talvolta in brevi piani costieri, dovuti in parte all'erosione delle acque e in parte scavati e spianati dal vento. In corrispondenza a questi piani, l'oceano (soggetto a forti maree e a violenti mareggiate) accumula sulla spiaggia dei cordoni di ciottoli (*albardones*), alti sino a 10-15 m. sopra il suo livello medio, che sbarrano le foci dei torrenti, trasformandole in stagni piú o meno estesi. Questi stagni si svuotano per incisione del cordone littorale quando le acque li riempiono sino a traboccare, ovvero per disseccamento. Dietro questi stagni recenti, si notano talvolta delle depressioni piú interne, allungate parallelamente alla costa e delimitate da cordoni littorali antichi, dispoti ad archi concentrici intorno alla costa attuale. L'esempio piú tipico si osserva sulla piatta fascia costiera a S della penisola Aristazábal (di fronte all'isola Quintana), dove quattro cordoni concentrici, il piú interno dei quali é situato a 4.5 km. dalla costa, alti sino a 40 metri s. m., nettamente rilevati e regolarmente arcuati intorno alla spiaggia attuale, delimitano alcune depressioni allungate che si trasformano in stagni dopo le pioggie.

Una quarta categoria di depressioni chiuse é rappresentata da piccole conche di sprofondamento aperte nei terreni arenaceo-argillosi del Cretaceo superiore e nei sedimenti tufacei dell'Eocene. Queste conche, dette *resumideros*, sono dovute a lenta asportazione dei materiali sabbiosi e tufacei incoerenti per opera delle acque circolanti a poca profonditá nel sottosuolo, e che vi aprono delle piccole caverne la cui volta viene a crollare. Le depressioni si allineano per lo piú in serie sul fondo delle vallecole, nelle regioni a *bad lands*. Hanno quasi sempre piccolo diametro e perció scarsa importanza morfologica.

La classificazione esposta non é sempre rigorosamente applicabile, essendovi depressioni di origine complessa, dovute cioé al concorso di vari fattori, endogeni ed esogeni. Cosí alcune conche di escavazione eolica si trovano sul fondo di piccole valli scavate dalle acque correnti e di cui riescono a interrompere la continuitá. Le depressioni di sprofondamento tettonico, vengono ampliate sia dalle acque di scorrimento, che ne incidono e frastagliano i margini, aprendovi delle vallicelle che convengono radialmene sul fondo della depressione; sia dal vento, che smuove ed asporta il fino detrito accumulato sul fondo, inpedendo il riempimento della depressione che anzi concorre ad ampliare ed approfondire. Due o piú depressioni

contigue possono cosí riunirsi in una cavitá unica di forma irregolare od allungata a guisa di valle, a seconda della originaria distribuzione delle conche. Da un piccolo sprofondamento circolare o da un infossamento tettonico, puó avere origine col tempo una depressione assai maggiore, che sebbene provocata inizialmente dalle dislocazioni, fu scavata poi in gran parte dalle acque e dal vento. L'ampliamento delle conche tettoniche per opera dell'erosione, fa spesso scomparire ogni traccia superficiale delle faglie; per cui, nella maggioranza dei casi, é impossibile accertare se la conca dipende da un infossamento tettonico, o se é invece il prodotto dell'escavazione eolica. Ció spiega anche il disaccordo degli autori in riguardo all'-origine delle depressioni chiuse della Patagonia.

Un'origine complessa spetta sicuramente alla grande depressione o Cuenca de Sarmiento, limitata a ponente dalla Sierra de San Bernardo e nel resto del suo contorno dal margine scarpato dell'altipiano a struttura tabulare. La conca ha fondo piano-alluvionale ed é parzialmente occupata da due estesi bacini lacustri, alimentati dalle acque che scendono dalle Ande per mezzo del Rio Senguerr e che ne escono poi col nome di Rio Chico (1).

La conca del lago Musters (473 km.^{2}), come aveva giá notato Keidel (2), occupa il fondo di un'ampia sinclinale diretta da S a N, riempita originariamente dalle erodibili formazioni del Cretaceo superiore e del Terziario inferiore e limitata lateralmente da due anticlinali a nuclei resistenti, che sorgono rispettivamente sulla sponda occidentale ed orientale del lago. Lo svuotamento della sinclinale per opera dell'acqua e del vento, seguito da un movimento postumo di affondamento, che accentuó la concavitá della piega (3), e dallo sbarramento della sua imboccatura meridionale per mezzo delle alluvioni del Senguerr, dánno una spiegazione plausibile delle formazione del lago. Il bacino del Coli Huàpi (772 km.) é limitato a ponente da una lunga anticlinale, che forma la dorsale situata fra i due laghi, e a S e a E da una regione a struttura tabulare, con pieghe molto dolci. Gli strati tendono a deprimersi a bacino in corrispondenza al lago e al piano alluvionale di Sarmiento. Sul lato sud-orientale del Coli Huapi, la coperta sedimentaria é dislocata da piccole flessure e faglie, dirette le une parallelamente alla sponda orientale del lago e le altre alla sponda meridionale. L'area lacustre e la pianura alluvionale di Sarmiento, corrisponde ad una zona di avvallamento in parte per piega e in parte per faglie, che é stata sovrescavata ed ampliata dall'erosione delle acque e del vento.

(1) L'uscita del Rio Chico dal coli Huàpi viene sbarrata a volte da un cordone sabbioso, edificato dalle onde e dal vento e che lascià il fiume a secco per periodi di anni. Windhausen, A. *Apuntes sobre el sistema hidrográfico del Rio Senguerr*, Anales Sociedad Argentina de Estudios Geográficos "Gaea," 1925. No. 1.

(2) Keidel. *Ueber das patagonische Tafelland* ecc. *Op. cit.*

(3) La conca lacustre si continua a N in un'ampia depressione valliva, costellata di piatte conche d'escavazione eolica e limitata a ponente dall'anticlinale del Cerro del Castillo, fagliata lungo il margine della valle: la valle corrisponde alla zolla profondata.

ABSTRACT.

ORIGINE DES DÉPRESSIONS FERMÉES DE LA REGION DU GOLFE DE SAINT GEORGE (PATAGONIE).

La région qui s'étends à l'entour du Golfe de Saint George est formée par une succession de plateaux (mesetas), à structure tabulaire et disloqués par des failles. Sur la surface des plateaux et sur le fond des vallées s'ouvrent plusieurs dépressions fermées, de dimensions très variées (avec un diamètre qui va de quelques dizaines de metres jusqu'à plusieurs kilomètres) et plus ou moins profondes. Les cuvettes peuvent être parties, à l'égard de leur origine, en: *dépressions d'origine tectonique*, dûes a des effondrements du sol limités par des failles, *dépressions de creusement éolien* et *dépressions de barrage* (déterminé par des cordons littoraux). Il y a aussi des cuvettes dont la formation est dûe en partie a des dislocations et en partie a l'érosion de l'eau et du vent. Tel est le cas de la grande Cuenca de Sarmiento, partialement occupée par les lacs Musters et Coli Huàpi.

64. IL DEVONICO DELLA REGIONE SUBANDINA DELL'ARGENTINA SETTENTRIONALE.

PER

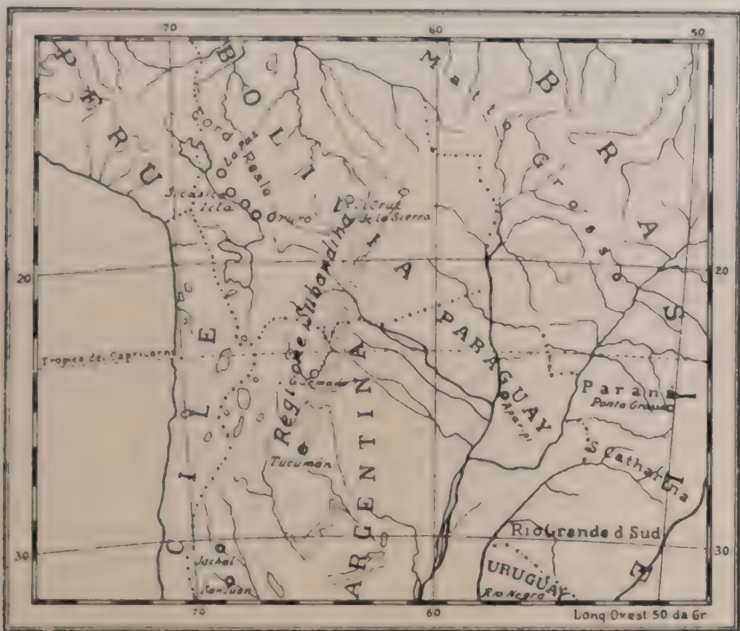
EGIDIO FERUGLIO.

La regione subandina dell'Argentina settentrionale comprende la fascia piú esterna delle Ande, che decorre ininterrotta da Tucumán (27° lat. Sud) sino al confine boliviano, proseguendo ai piedi della Cordigliera fino a Santa Cruz de la Sierra (18° lat. Sud.) È un complesso di rilievi a pieghe asimmetriche, dirette da S a N, in coincidenza con le dorsali orografiche, di solito non molto compresse, piú inclinate e talvolta rovesciate verso la pianura del Chaco. Il nucleo visibile delle anticlinali é costituito da una serie di argilloscisti, intercalati a luoghi da strati e banchi di arenarie quarzitiche, con una potenza complessiva di alcune centinaia di metri. Questa serie é coperta da una potente coltre di sedimenti continentali, compresi cronologicamente fra il Permico ed il Terziario superiore e divisi in due parti da un orizzonte calcareo marino (d'etá liasica secondo alcuni autori e cretacea secondo altri), che s'intercala un po' sotto il mezzo del loro spessore.

Il complesso argilloscistoso e arenaceo che forma il nucleo delle anticlinal, é stato ascritto al Devonico da BONARELLI [1], che ha basato il suo riferimento sulla identitá litologica coi terreni devonici della Bolivia e in ispecial modo col Devonico fossilifero di Tarija, e sul trovamento di alcuni fossili devonici nella regione subandina Boliviana, in prosecuzinoe di quella argentina. Questi terreni si estendono in territorio argentino sopra un'estensione di circa 3° di latitudine. L'unico fossile finora segnalatovi era un esemplare di *Orthis* (?) *laticostata* d'Orb., proveniente dall'Angostura del Rio Grande di Jujuy, presso La Mendieta. Recentemente io ho rinvenuto una localitá fossilifera alla testata dell'Arroyo Moralito, che scende dal fianco orientale della Sierra de Zapla, a N di San Pedro de Jujuy, nella regione del Quemado (24° lat. Sud). La Sierra de Zapla

[1]) BONARELLI, G. *Tercera contribución al conocimiento geológico de las regiones petrolíferas subandinas del Norte.* Anales de la Dirección de Minas, G. e H., tomo XV, N° 1. Buenos Aires, 1921.

coincide tettonicamente con un'anticlinale, nel cui nucleo compaiono: 1) argilloscisti micacei, grigi, grigio-lucenti e nerastri, intercalati da strati e banchi di un'arenaria quarzitca biancastra, grigia e violacea. Su questi



terreni si adagiano in apparente concordanza 2) arenarie quarzose rosso-violacee, di circa 200 m. di spessore. Coprono le arenarie testé menzionate e da esse separate per mezzo di una breccia di discordanza 3) arenarie rosse e strati calcarei con intercalazioni argillose varicolori (prevalentemente verdastre), cui succede 4) un complesso di arenarie e argille rosse d'etá mesozoica e terziaria, potente parecchie centinaia di metri. Questi terreni sono piegati dapprima ad ampia sinclinale, situata ai piedi dell'anticlinale della Sierra de Zapla, e curvati quindi ad anticlinale. I fossili devonici qui sotto elencati provengono dalla serie scistoso-arenacea inferiore e si trovavano inclusi nelle arenarie quarzitiche:

Chonetes falklandica M. et Sh.
,, *gortanii* n.f.
Rhynchonella sp. ind.
Rhynchonella sp.
Leptodesma sp. ind.
Actinopteria aff. *eschwegei* Clarke
Nucula?
Bucaniella rectangularis Knod
,, *quemadensis* n. f.
Loxonema aff. *attenuata* Hall

Tentaculites crotalinus Salter
Orthoceras sp.
Homalonotus argentinus n. f.
Homalonotus? groeberi n. f.
Phacopina chojnacotensis (Swartz)
„ *bonarellii* n. f.
Cryphaeus australis Clarke var. rotundatus Kozl.

La piccola fauna conta 12 forme determinate specificamente, delle quali 5 sono nuove. Tutte le 7 forme note si trovano nella serie di Icla in Bolivia. Inoltre 2 di esse furono segnalate nell'Eodevonico delle isole Falkland; 3 nell'Eodevonico di Jachal (San Juan), in Argentina; 2 nell'Eodevonico dell'Uruguay; 3 nell'Eodevonico di Paraná e Matto Grosso; 4 nell'Eodevonico di Bokkeveld nella Colonia del Capo. Una sola forma é comune col Mesodevonico di Maecurú in Brasile e col Mesodevonico di Sicasica in Bolivia. Delle 5 forme nuove, 2 sono affini a forme dell'Eodevonico di Jachal; 2 a forme della serie di Icla; 2 della serie di Sicasica; 2 di Maecurú e I di Paraná e Matto Grosso. La maggiore comunanza di specie si verifica dunque con la serie di Icla, in Bolivia, essendo pure notevoli le affinitá con l'Eodevonico di San Juan nell'Argentina e di Bokkeveld nella Colonia del Capo. Gli strati fossiliferi del Quemado si possono pertanto omologare con la serie di Icla, ritenuta equivalente dell'Oriskaniano (Eodevonico superiore) dello Stato di New York ([1]). Alla stretta relazione faunistica con la serie di Icla, si aggiunge l'identitá della composizione litologica. Tanto ad Icla quanto nell'Argentina settentrionale il Devonico risulta costituito da argilloscisti grigi e nerastri, con intercalati strati e banchi di un'arenaria fina quarzitica. Queste analogie dimostrano l'esistenza, durante il Devonico inferiore, di una zona di mare poco profondo che si estendeva sopra una vasta parte dell'America meridionale, communicando direttamente con l'Africa australe. Incerta per ora é la posizione stratigrafica delle arenarie quarzose rosso-violacee che coprono in apparente concordanza la serie scistoso-arenacea fossilifera del Quemado e che potrebbero eventualmente corrispondere alle arenarie di Huamampampa (parte superiore della serie di Icla.)

[1]) Kozlowsky, R. *Faune dévonienne de Bolivie.* Annales de Paléontologie, XII. Paris, 1923.

Abstract.

La région subandine de l'Argentine septentrionale est formée par un faisceau de plis asymétriques, dirigés de S a N. Le noyau des anticlinaux est constitué par une série de schistes argileux, altenants parfois avec des couches et bancs de grés

quartzitique. Les terrains étaient attribués au Dévonique pour leur identité lithologique avec le Dévonique fossilfère de Bolivie. Il n'y a pas longtemps j'ai signalé une localité fossilfère dans la région du Quemado (24° lat. S.) La petite faune recueillie comprend 12 formes, dont 5 sont nouvelles. Toutes les 7 formes connues son communes avec la faune de Icla, en Bolivie, considérée comme représentante du Oriskanien (Eodévonique supérieur). Elle est aussi notable l'affinité avec l'Eodévonique de San Juan en Argentine, de Parana et Matto Grosso et avec l'Eodévonique de Bokkeveld (Colonie du Cap).

65. DESCRIPTION D'UNE NOUVELLE CARTE GEOLOGIQUE DE DE LA TUNISIE A L'ECHELLE DE 1/ 500 000

dressée en vue de la publication de la Carte Géologique Internationale de l'Afrique.

MARCEL SOLIGNAC.

Docteur ès Sciences.
Chef du Service Géologique de Tunisie.

La Carte dont la description fait l'objet de la présente communication a été dresée en vue de son incorporation à la Carte Géologique Internationale de l'Afrique, conformément au voeu exprimé, en 1926, par le XIV. Congrès Géologique International de Madrid.

Elle est destinée à remplacer la "*Carte géologique provisoire de la Tunisie*" à l'échelle de 1:800 000 par F. AUBERT, dont la publication remonte à 1892, document éminemment apprécié et tojours utile, mais qui n'est plus en harmonie avec l'état actuel de nos connaissances sur cette partie de l'Afrique Mineure.

Le fond topographique, adopté pour la confection de la nouvelle carte est celui de la Carte de la Tunisie, en courbes de niveau, à l'échelle de 1:500 000, par le Service Géographique de l'Armée française. La distribution géographique des diverses formations géologiques est celle qui résulte de la compilation ou de la consultation des documents suivants:—Carte géologique provisoire de la Régence de Tunis à 1:800,000 par F. AUBERT; Carte géologique de la Tunisie Centrale à 1:200,000 par L. PERVINQUIERE (1903); nombreux tracés inédits à 1: 50 000 et 1: 100 000 par MM. BEZIERS et GEVREY, Ingénieurs au Service des Mines de Tunis; feuilles Bizerte, Tabarca-La Galite, Tunis, Cap Bon, Gafsa, Tozeur, Kebili, de la Carte géologique provisoire à 1: 200 000 de la Tunisie, publiées par l'auteur, de 1924 à 1929, sous les auspices de la Direction Générale des Travaux Publics de la Régence; levés inédits de l'auteur dans diverses parties du Centre, du Sud et de l'Extrême-Sud tunisiens.

L'échelle stratigraphique adoptée comporte les 16 subdivisions suivantes: Paléozoïque (Silurien?) - Trias - Lias - Jurassique (Oolithique

inférieur, moyen et supérieur) - Eocrétacé - Mésocrétacé - Néocrétacé - Eo et Mésonummulitique (du Montien au Bartonien) - Meso et Néonummulitique (du Bartonien au Chattien) - Néogène inférieur-Néogène moyen (Vindobonien) - Néogène moyen (Sahélien-Pontien) - Néogène moyen (Pliocène marin et continental, comprenant parfois du Pontien non horizonté) - Pleistocène - Holocène (Dunes et Formations actuelles) - Roches ignées.

Enfin, les principaux gisements miniers (Fer, Plomb, Zinc, Cuivre, Arsenic, Phosphate de chaux, Lignite, Hydrocarbures, Sels) sont figurés sous des signes et des symboles appropriés.

On trouvera, dans ce qui suit, une description succincte des caractères les plus essentiels des formations géologiques tunisiennes.

I. Description Stratigraphique.

Paléozoïque

Silurien?

C'est au Silurien que M. P. Termier ([11])* croit pouvoir rapporter, au moins provisoirement, les schistes micacés et les quartzites du djebel Haïrech, dans la vallée de la Medjerda, par comparaison avec des assises similaires de l'Algérie et du Maroc. Jusqu'ici, il n'a pas été trouvé de fossiles dans cette localité dont on ne retrouve l'équivalent en aucun autre point du territoire tunisien. Outre les affinités lithologiques précitées, l'attribution de M. P. Termier se base sur des considérations tectoniques importantes.

Les schistes et quartzites de l'Haïrech possèdent, en effet, un système de plissement compliqué, contrastant avec la direction N.N.E.-S.S.O. habituelle des plis de la Tunisie septentrionale. Ils constituent le coeur d'un vaste dôme, édifié à l'époque tertiaire, et l'on observe une discordance profonde entre ce coeur et la coupole crétacée-éocène qui le surmonte, celle-ci ne portant que les traces du mouvement alpin. Ainsi donc, par le faciès particulier de ses assises et par sa tectonique spéciale, le djebel Haïrech mérite évidemment une place à part dans le tableau stratigraphique de la Tunisie, et le moins que l'on puisse dire de lui c'est qu'il très vraisemblablement paléozoïque.

Permien.

Le Permien est, peut-être, représenté par des grès rouges que l'on rencontre souvent à la base du Trias, notamment dans le grand affleurement triasique qui traverse en écharpe la Tunisie depuis la frontière algérienne (djebel Ouenza) jusqu'au golfe de Bizerte. Cette même forma-

*Les nombres entre crochets correspondent à ceux de la liste bibliographique

tion est également bien développée dans l'Extrême-Sud (région de Kirchaou) où, faute de fossiles, elle est inséparable du Trias, auquel elle est subordonnée.

Mesozoïque.

Trias.

Le Trias est abondamment représenté sous son faciès germanique. Il est constitué par des marnes bariolées, riches en cristaux bipyramidés de quartz enfumé, des grès en plaquettes et multicolores, alternant avec des gypses saccharoïdes en bancs massifs et se terminant, dans le cas des séries complètes (Hédil, dj. Baouala), par une assise de dolomies. Du sel s'y trouve presque toujours associé sous forme de lentilles et parfois de bancs épais (dj. Adifa) intercalés dans les marnes bariolées ou subordonnés à elles (dj. Lorbeus, dj. Abdallah ben Cheid.) Enfin, des amas de roches éruptives, microgabbros, dolérites, etc., généralement englobées dans le terme très imprécis *d'ophites*, sont associées à ce complexe: ce sont toujours des roches vertes à cause de leur richesse en minéraux secondaires d'altération, dipyre et épidote. On ne sait rien des appareils éruptifs qui leur ont donné naissance.

L'aspect des massifs triasiques est toujours chaotique. Il paraît résulter, indépendamment des modalités de l'orogénèse régionale, de deux causes absolument intrinsèques, l'une tectonique dûe au *modus habendi* particulier au sel, dont la tendance naturelle est de s'extravaser sous forme de *pustules* ou *d'eczémas*, l'autre chimique dûe au foisonnement des masses d'anhydrite se transformant en gypse.

Les fossiles sont assez rares. On y a trouvé cependant ([15]; [9]) des bivalves (*Myophoria Goldfussi*, *Myophoria vulgaris*, *Alectryonia Montis caprilis*) et des plantes (*Equisetites arenaceus*) caractéristiques du Trias germanique.

Le même faciès se retrouve sans modifications dans tous les affleurements de Trias situés au Nord des grands Chotts du Sud Tunisien.

Au Sud de cette région, l'aspect se modifie considérablement. Au djebel Tebaga, près de Médenine, et surtout dans le grand bombement qui correspond à la Djefara, les grès rouges, permiens ou triasiques, de Kirchaou sont surmontés d'une puissante série comprenant des alternances de marnes bariolées, principalement rouge lie de vin et vertes, de calcaires, de grès et de dolomies fosilifères (*Myophoria Goldfussi*, *Myacites cf. muscoloïdes*) et se terminant par une énorme épaisseur de gypse saccharoïde, blanc, rouge ou noir.([21]) dans lequel peuvent se trouver des amas de sels sodiques et potassiques dont le lessivage engendre les dépôts salifères de certaines *sebkhas* de la région de Sidi Toui.

L'aspect du Trias de l'Extrême-Sud Tunisien n'est pas sans rappeler celui des *Molteno Beds* et des *Red Beds*, étages des Stormberg series appartenant au *système du Karroo* Sud-Africain : l'âge des deux formations, la tunisienne et la sud-africaine, est d'ailleurs le même.

Lias et Oolithique.

Le Lias est confiné dans les sommets les plus élevés de la Dorsale tunisienne, en Tunisie septentrionale, et dans quelques massifs peu importants de l'Extrême-Sud (dj. Tadjera, dj. Tebaga, Ksar Beni Ikrzer.) Dans le Centre et le Sud du pays, il est authentiquement inexistant.

Il est fréquemment superposé au Trias (dj. Ressas, dj. Azreck, dj. Djedidi, dj. Zaghouan, dj. Kohol, dj. Ekirine pour le Nord, dj. Tadjera, dj. Tebaga, Ksar Beni Ikrzer pour l'Extrême-Sud).

Il consiste essentiellement en calcaires massifs, cristallins et siliceux, très durs, donnant naissance à des crêtes déchiquetées, à l'aspect pittoresque. On y recontre aussi des calcaires oolithiques et marmoréens, comme au dj. Oust et au dj. Aziz, des calcaires rubannés, de petites assises marneuses et des fausses brèches dont l'aspect a, depuis longtemps, été comparé à celui de la Brèche du Télégraphe du Briançonnais. Les fossiles n'y sont pas rares. Plusieurs faunes d'Ammonoïdés, de Brachiopodes et de Stromatoporidés ont permis d'y définir plusieurs zones allant du Sinémurien à l'Analénien et comparables aux zones classiques de la Cuvette Germanique.(9)

Il n'a pas encore été possible d'établir avec précision l'âge des couches les plus inférieures du Lias, de sorte que l'on ne saisit pas encore les conditions suivant lesquelles la mer jurassique a succédé aux lagunes du Trias. L'hypothèse d'une discordance, correspondant à une lacune stratigraphique entre les deux groupes triasique et jurassique, est possible mais elle ne se trouve nulle part réellement vérifiée.

L'Oolithique proprement dit est assez peu développé dans la Tunisie septentrionale. Ses affleurements sont circonscrits autour des massifs liasiques. Malgré sa faible puissance, il a été cependant possible, grâce à la présence de nombreux fossiles, d'y caractériser les deux groupes de l'Oolithique moyen et de l'Oolithique supérieur. Le tableu I résume l'ensemble de nos connaissances actuelles sur le Jurassique de la Tunisie du Nord.

L'absence de l'Oolithique inférieur est à signaler. Etant donné qu'il n'existe aucune discordance entre l'Aalénien et l'Oolithique (sauf en quelques points où un tel accident se révèle comme d'origine tectonique), il est vraisemblable que l'Oolithique inférieur doit être représenté par des assises jusqu'à présent non fossilifères, qui sont actuellement rapportées au groupe moyen (dj. Oust).

Une mention spéciale doit être accordée au Jurassique du dj. Ichkeul (ou Achkel), montagne isolée au milieu de la plaine de Mateur et bordant la rive méridionale de la Garaet Achkel, non loin de Bizerte. Ici, le Jurassique est constitué par des schistes séricíteux à cordiérite et ottrélite, renfermant des débris difficilement déterminables de Bélemnites, puis par des schistes verts alternant avec de gros bancs de calcaires rougeâtres, plus ou moins marmoréens, dans lesquels on trouve *Aptychus Beyrichi*, paraissant indiquer la présence du Tithonique. Une grande partie de ces calcaires a été soumise à une dolomitisation intense que M. P. Termier et l'auteur atribuent à une sorte de métamorphisme hydrothermal à propos duquel des recherches sont en cours.

Dans l'Extrême-Sud, l'Oolithique possède une extension considérable. Il occupe [25] la majeure partie du massif des Ouderna ainsi que tout l'espace entre l'Oued Blell et la haute falaise crétacée de Douirat. Il est particulièrement développé et fossilifère aux environs de Foum Tatahouine. Il se poursuit au Nord par le djebel Ghoumrassen. On le suit, au Sud, jusqu'à la Garaet el Mekmène et au Touil el Asfer où il passe en Tripolitaine.

Dans cette contrée, l'Oolithique repose tantôt directement sur le Trias, tantôt sur le Lias (Ksar Beni Ikrzer). Son faciès diffère totalement de celui de la Tunisie septentrionale. Les recherches stratigraphiques de Le Mesle [26], puis de lieutenant Henry Jourday [27] et d'Alexandre Joly ont montré qu'il se compose d'argiles gypseuses, de marnes jaune verdâtre, de calcaires roux plus ou moins dolomitiques, de grès blancs ou jaunes, et dans lesquelles on n'a trouvé, en fait de fossiles, hormis un seul fragment d'ammonite, que des Crinoïdes, des Echinides, des Brachiopodes et des Mollusques. Ces alternances constituent une série parfaitement continue dans laquelle on distingue, tout en bas, un niveau fossilifère correspondant au *Bathonien inférieur*, puis un niveau moyen à rarissimes Céphalopodes dont l'un, voisin de *Pachyceras coronatum*, semble indiquer la présence du *Callovien*, puis encore un *Oxfordien* à Rhynchonelles, et enfin, tout en haut, un dernier niveau fossilifère *Kiméridgien*.

M. H. Douvillé qui a étudié les faunes provenant des divers niveaux du Jurassique de l'Extrême-Sud tunisien, leur trouve une analogie de faciès, en même temps qu'une analogie lithologique, avec les faunes du Jurassique d'Abyssinie et de la Syrie septentrionale.

Crétacé.

Le début du Crétacé marque l'avènement d'un régime essentiellement marin pour l'ensemble de la Tunisie. Pendant toute la durée de cette époque, et même pendant une grande partie de l'époque Nummulitique, la Tunisie septentrionale n'a pas cessé de faire partie d'une mer profonde, que la faune bathyale du Portlandien faisait déjà prévoir. C'est à cette mer,

dont les dépôts ont un caractère géosynclinal que les géologues algériens ont parfois donné le nom de *branche tellienne du géosynclinal méditerranéen*, indiquant une ramification du grand géosynclinal méditerranéen au Sud des amygdales hercyniennes du littoral algérien (massif d'Alger, Kabylies, Edough).

L'extension de la mer crétacée vers le Sud s'est faite progressivement jusqu'à atteindre son maximum au Mésocrétacé; tandisque, avec le Néocrétacé, a commencé une phase de régression vers le Nord régression qui s'est de plus en plus accentuée pendant la période tertiaire.

Le *Valanginien* et *l'Hauterivien bathyaux* sont localisés, en Tunisie septentrionale, autour des affleurements jurassiques précédemment décrits. Ils comprennent un énorme développement d'assises marneuses, marno-calcaires et calcaires succédant, en concordance de stratification aux couches de l'Oolithique supérieur. On y retrouve à peu près toutes les zones paléontologiques du géosynclinal classique de la Fosse Vocontienne ([illegible]) :—

1) Zone à *Thurmannia Boissieri* (dj. Oust, dj. Melloussi) avec *Thurmannia lucensis, T. Salientina, T. Thurmani, T. Roubaudi, T. pertransiens, Berriasella Callisto, Phylloceras semisulcatum, Hibolites pistilliformis*, etc. Cette zone correspond au sous-étage *Berriasien*.
2) Zone à *Kilianella Roubaudiana* (dj. Oust) avec *Kilianella Roubaudiana, K. Paquieri, Neocomites neocomiensis, Holcostephanus Astierianus, Phylloceras Thetys, Lissoras Grasianum, Duvalia lata*, etc.
3) Zone à *Saynoceras verrucosum* (dj. Oust.)

Ces trois zones représentent le Valanginien. L'Hauterivien, développé au dj. Oust, au dj. Zaghouan, au dj. 'Mecella, comprend:

4) Zone à *Acanthodiscus radiatus*.
5) Zone à *Crioceras Duvali* avec: *Lissoceras Grasianum, Holcostephanus cf. hispanicus, Aptychus Didayi*.

Dans le Centre et le Sud de la Tunisie, le Valanginien et l'Hauterivien sont inséparables du Barrémien ([illegible]; [illegible]) avec lequel ils forment un complexe marno-gréseux d'origine néritique et riche en Echinides. Ce *faciès à Spatangues* se rencontre notamment aux djebels Mrhila et Ben Younès.

Plus au Sud dans le dôme du Chott el Fedjedj, l'auteur a constaté récemment, l'existence d'un Valanginien-Hauterivien à faciès saumâtre passant à un faciès continental. Ce Crétacé comprend à la base, un système d'argiles multicolores et gypsifères alternant avec de petits bancs

de grès et de calcaires, et rappelant assez bien le faciès du Trias; puis viennent des alternances de grès grossiers, de sables et d'argiles rouges.

L'assise inférieure a fourni des fossiles qui sont identiques ou très voisins de certaines espèces du Purbeckien et du Wealdien d'Angleterre et des couches de Uitenhage, dans le Sud Africain. Ce sont, notamment: *Cyrena media*, *Cyrena* cf. *parva*, *Corbula* sp., *Vicarya* sp., *Rostellaria* sp., un Pectinidé intermédiaire entre *Pecten cottaldianus* et *Pecten orbicularis*, *Mytilus* cf. *uitenhagensis*.

Il s'agit donc d'un Eocrétacé trè bas, peut-être même d'un terme intermédiaire entre le Jurassique supérieur et l'Eocrétacé.

Quant à l'assise supérieure, argilo-gréseuse, elle abonde en restes de végétaux, malheuresement très ferrugineux, qui apparaissent déjà dans les couches gréseuses de l'assise inférieure (dj. Klikr). Leur étude a été entreprise par M. l'abbé CARPENTIER, Professeur à la Faculté catholique de Lille.

L'auteur n'a pas retrouvé cet Eocrétacé si special dans l'Extrême Sul. Il doit cependant y exister au dessus des dernières couches de calcaires jurassique, mais le contact est masqué par des terrains récents et des dunes. On le retrouve, en effet, exactement dans cette situation stratigraphique, le long du prolongement du dit contact, en Tripolitaine, où il a fourni à M. l'Ingénieur D. ZACCAGNA la belle flore wealdienne suivante ([21]): *Cladophlebis Albertsii* Brongt., *Cladophlebis Zaccagnai* Princ., *Yuccites* sp., *Dioonites Buchianus* Bornm., *Sphenolepidium Kurrianum* Heer., *Becklesia anomala* Seward.

L'étage *Barrêmien* possède, en Tunisie septentrionale, une répartition analogue à celle des deux étages inférieurs, c'est à dire autour des dômes jurassiques. Cependant on en connaît encore plusieurs affleurements dans la région de Tunis (Mohammedia, Argoub Sidi Smir, dj. Mergueb, Beauvour, dj. Bou Kournine, etc.) et dans celle de Tebourba (dj. Guelguemène et Boulahouadjeb, Djedaria, Oued Tazega, etc).

Ses assises bathyales consistent aussi en marnes sombres, marnocalcaires et calcaires. Les zones paléontologiques suivantes y ont été reconnues ([9]) :—

1) Zone à *Desmoceras Savni* (dj. Oust, Guelguemène, Zaghouan, Bou Kournine) avec *Desmoceras Sayni*, *Puzosia aff. ligata*, *Phylloceras semisulcatum*, *P. infundibulum*, *Holcodiscus Sophonisba*, *H. Geronimoe*, *H. astierianus*, *Bochianites neocomiensis*, *Aptychus angulicostatus*, *Belemnopsis binervius*, *Duvalia dilatata*, *D. Emerici*.

2) Zone à *Parahoplites angulicostatus* (Oust, Beauvour, Guelguemène, Zaghouan, Bou Kournine, Gorges de la Siliana, etc.) avec: *Parahoplites angulicostatus*, *Puzosia* cf.

Angladei, Leptoceras Cirtae, Crioceras hammatoptychum, C. Sabaudianum, C. angulicostatum, Ancyloceras Lardyi, Duvalia Grasi.

3) Zone à *Pulchellia Pulchella* (Oust, Mohammedia, Argoub Smir, Mergueb, Beauvour, Bou Kournine, etc.) avec: *Pulchellia Heinzi, P. Chalmasi, P. Ouachensis, P. Moltoi, Desmoceras strettostoma, Puzosia Nabdalsa, P. Melchioris, Costidiscus recticostatus, Silesites Seranonis, Simbirskites* sp., *Duvalia lata, Oxytheuthis Brunswicencis.*

4) Zone à *Heteroceras Astierianum* (Oust, Zebbas, Mohammedia, Argoub Sidi Smir, Mergueb, etc.) avec: *Heteroceras Astierianum, Crioceras recticostatum, Macroscaphites, Ficheuri, M. striatisulcatus, Lytoceras crebrisulcatum, Jaubertella Jaubertiana, Desmoceras Munieri, Puzosia? Annibal, P. Ibrahim, Psilotissotia Cortazari, Phylloceras Rouyanum, P. Ernesti, P. Carlavanti, Silisites Seranonis, Belemnopsis semicanaliculatus.*

5) Zone à *Macroscaphites Yvani* (Oust, Zebbas, Mohammedia, Argoub Sidi Smir, Mergueb, Bou Kournine, etc.) avec *Macroscaphites Yvani, Hoplites cf. somalicus.*

Le *Barrêmien* néritique du Centre et du Sud est pratiquement inséparable du complexe Valanginien-Hauterivien ([15]) dont le faciès à Spantangues a été signalé précédemment (Mrhila., BenYounès). Cependant, au djebel Berrani, sur le périclinal Nord-Est du dôme du Chott el Fedjedj, l'auteur a rencontré un Barrêmien bien individualisé, au dessus des dernières assises d'argiles et de grès à bois fossiles de l'Hauterivien. Cet étage comprend un horizon inférieur de marnes et de calcaires à *Natica Cornueliana*, et un horizon supérieur de calcaires cristallins, à *faciès urgonien*, renfermant *Requienia ammonea, Nerinea Pauli, Terebratula sella, Heteraster oblongus.*

L'absence du Barrêmien dans l'Extrême-Sud semble indiquer une régression de la mer barrêmienne par rapport à la mer du Néocomien inférieur.

L'*Aptien* bathyal du Nord de la Tunisie a la même répartition géographique que le Barrêmien. Il possède également une constitution lithologique analogue, bien que plus marneuse. De nombreux fossiles permettent d'y distinguer deux zones:

1) Zone à *Parahoplites Deshayesi* et *Ancyloceras Matheroni*, correspondant au sous-étage *Bédoulien.* Elle est assez bien représentée aux dj. Oust, Kohol, Asiz, Mecella, Bou Kournine et à Aïn el Asker par des marno-calcaires à *Parahoplites fissicostatus* et *P. crassicostatus.*

2) Zone à *Oppelia Nisus*, correspondant au sous-étage *Gargasien*. On la trouve dans les localités suivantes: dj. Oust, Armand Colin, dj. Zebbas, Argoub Sidi Smir, dj. Bou Djebla, dj. Guelguemène, oued Tazega, Kef en Nsoura, dj. Baouala, Djedaria, dj. Ahmar, Zaghouan, dj. Kohol, Thuburbo Majus, dj. Azib, dj. Mecella, dj. Bou Kournine, dj. Bou Mouss, Oued Zerga, Testour, vallée de la Siliana, Bou Arada, Pont du Fahs, etc. Les principales et les plus caractéristiques espéces rencontrées sont: *Oppelia Nisus, Douvilleiceras Bigoureti, D. Abichi, D. Martini, Parahoplites gargasensis, P. Milletianus, P. Nolani, Hoplites lurensis, Lytoceras Numidum, Uhligella Monicae, U. Boussaci, Puzosia Angladei, P. getulina, P. Mayoriana, Desmoceras Dupinianum, D. akuschaense, D. clansayense, D. Revoili, Silesites Seranonis* var. *interpositus, S. Seranonis var. balearense, S. ebusitanus, Ptychoceras laeve, Kilianella Mathô, Trochleiceras balearense, Phylloceras Guettardi, P. Rouyanum, P. lateumbilicatum, P. Grothi, P. Velledae, Magellania tamarindus, Isocrinus askerensis, Pseudobelus aptiensis Neohibolites Fallauxi.*

L'Aptien du Centre et du Sud de la Tunisie est strictement néritique. Ses calcaires, marnes et quartzites forment l'ossature des grandes montagnes de cette contrée (djebels Serdj, Bargou, Belouta, Bou el Hanèche, Zrissa, Slata, Hameïma, Azred, Hamra, Semmama, Mrhila, Chaambi, Trozza, Batene, Harraba, Guern Alfaya, Haïra, Roumane, Nouba, Serraguia, Diabit, etc). Sa faune fossile est peu variée et comprend des formes communes à l'Eocrétacé ([15].) Comme espèces spéciales à l'Aptien, il faut citer: *Salenia prestensis, Pseudodiadema Malbosi, Hoplites fissicostatus.* La plupart des autres formes sont surtout des Echinides, des Brachiopodes et des Lamellibranches. On y trouve aussi, en grande abondance, des Foraminifères parmi lesquels *Orbitolina lenticularis* est l'espèce dominante.

Au djebel Berrani, dont il a été question précédemment, les calcaires à Orbitolines se différencient nettement du Barrêmien à faciès urgonien.

L'Aptien est inconnu au Sud des Chotts: la mer aptienne devait avoir sensiblement la même extension que la mer barrêmienne.

* * *

Le *Mésocrétacé* a été, pour la Tunisie, une ère de transgression maxima de la mer. Ses dépôts recouvrent la totalité du pays et s'avancent dans le Sahara jusqu'aux environs du 28ème parallèle où Haug et l'auteur l'ont décrit de la dépression de Djoua.([12]) Dans cette région, l'Albien fait suite au Carboniférien.

L'*Albien bathyal* de la Tunisie septentrionale et d'une partie de la Tunisie centrale est généralement constitué par des marno-calcaires gris foncé ou noirâtres, assez peu fossilifères. L'espèce la plus commune est *Mortoniceras inflatum* qui paraît définir une zone paléontologique voisine de la zone à *Mortoniceras Hugardianum* et *M. inflatum* de l'Albien alpino-dauphinois. Cet étage se rencontre dans les localités suivantes: Beauvour, dj. Ouiba, Bou Arada, gorge de la Siliana, Pont du Fahs, dj. Rihane, Ragoubet Bijga, djebels Azred, Hamra, Bou el Hanèche, Bargou, etc.

Dans le Sud (Bou Ramli, Oum Ali, Orbata, Diabit), l'Albien montre des alternances de marnes bariolées, gypsifères, et de calcaires gris ou multicolores en petits bancs, dans lesquelles PHILIPPE THOMAS [18] a signalé une faune fossile voisine de celle de l'Albien d'Utrillas, en Espagne, avec: *Arcomya fallax, Nerinea Utrillasi, Glauconia Picteti.*

Dans l'Extrême-Sud, au pied de la falaise du Dahar et, notamment, dans la région d'Aïn Remada, l'Albien paraît être représenté par des argiles vertes, des grès multicolores et des calcaires gréseux contenant des bois fossiles et de nombreux débris de Poissons qui ont été rapportés aux genres *Pycnodus, Lepidotus* et *Notidanus*. L. PERVINQUIÈRE pense que ces couches sont identiques aux couches albiennes à Poissons, décrites par HAUG, du Djoua.

Le *Cénomanien* a la même répartition géographique que l'Albien. Ses dépôts bathyaux s'étendent sur tout le Nord de la Tunisie et sur une grande partie de la région centrale, sensiblement jusqu'au parallèle de Thala. Le Cénomanien néritique recouvre les contrées du Sud et de l'Extrême-Sud, jusqu'à la dépression du Djoua dans le Sahara.

Le Cénomanien bathyal, constitué par des alternances de marnes et de calcaires avec prédominance des calcaires au sommet, et prédominance de calcaires en plaquettes à la base, présente les zones suivantes [9]:

1) Zone à *Mortoniceras inflatum* et *Turrilites Bergeri* (Kef en Nesoura, Bou Djebla, Sidi Selmane, Beauvour, Argoub Sidi Smir, dj. Ahmar, Sidi Mohamed en Nouali, dj. Oust, Pont du Fahs, dj. Rihane, Ragoubet Bijga, Solotos, dj. Kechtilou, Goubellat).

Cette zone représente le *Cénomanien inférieure* ou *Craconnien*. Elle possède une faune très riche de Rudistes et surtout d'Ammonites pyriteuses, parmi lesquelles apparaissent des types du Vraconnien de l'Inde (*Kosmatella Marut, Puzosia* cf. *diphylloïdes*, etc). Les espèces les plus répandues sont: *Mortoniceras inflatum, M. proratum, M. Bogbariense, M. Nicaisei, Acanthoceras Martimpreyi, Lytoceras Timotheanum, L. Dozei, L. Flicki, Phylloceras Velledae, P. Whiteavesi, P. deci-*

piens, P. ellipticum, Puzosia Paronae, P. Chirichensis, cf. *diphylloïdes, Bostrychoceras Thomasi, Forbesiceras obtectum, Sauvagesia Nicaisei, Durania Mortoni, Turrilites Bergerie T. Aumalensis, T. Kerimensis, T. Scheuchzerianus, T. Puzosianus, T. Costatus.*

2) Zone à *Acanthoceras Mantelli,* à laquelle se rattachent les calcaires blancs de Fedj el Adoum.

3) Zone à *Acanthoceras rotomagense* et *Acanthoceras Newboldi,* bien représentée au dj. Ouiba, dj. Aouinet, dj. Zebbas, dj. Zaghouan, Thibica, Ragoubet Bijga.

4) Zone à *Neolobites Vibrayeanus,* caractérisée seulement au dj. Bateune Slama.

Le Cénomanien devient plus marneux et fossilifère lorsque l'on s'approche de la partie méridionale de la Tunisie Centrale. Les condition bathyales y sont plus atténuées: aux faunes d'Ammonoïdés s'ajoute une faune importante de Lamellibranches, d'Echinides et d'Ostracés. C'est avec raison que L. Pervinquière a rapproché ce faciès du *faciès africano-syrien* de Zittel ([15]). La faune ammonitique présente ici cette particularité d'être entièrement dénuée de représentants des genres *Phylloceras* et *Lytoceras* qui abondent, au contraire, dans le Cénomanien de la Tunisie septentrionale.

Ce faciès central, comme l'appelle Pervinquière, se rencontre notamment aux points suivants: dj. Mrhila, Bargou, Serdj, à Bordj Debbich, au Koudiat el Hamra, dj. Slata, Zrissa, Bou el Hanèche, Bireno, Azered, Zbissa, Hamra, Ben Habess, Trozza.

Le géologue précité y a reconnu les quatre zones ci-dessous ([15]):

1) Zone à *Turrilites Bergeri* avec *Mortoniceras inflatum, Stoliczkaïa dispar* (Vraconnien).

2) Zone à *Acanthoceras rotomagense et A. Newboldi,* où abondent les Ostracés (surtout *Ostrea Syphax*) et les Echinides, particulièrement des *Hemiaster* (*Hemiaster batnensis*).

3) Zone à *Thomasinella punica.*

4) Zone à *Neolobites Vibrayeanus* avec *Ostrea olisiponensis, Heterodiadema libycum.*

Le Cénomanien du Sud de la Tunisie est bien connu grâce aux travaux de Ph. Thomas ([18]) et de L. Pervinquiere ([15]). Il est caractérisé par la moindre importance des marnes et leur remplacement partiel par des calcaires, des dolomies et des gypses. Au point de vue paléontologique, on constate l'extrême rareté des Ammonoïdés et le développement intense d'une faune néritique caractérisée par des Ostracés, des Lamellibranches, des Gastropodes, des Echinides.

On rencontre le Cénomanien aux djebels Nouba, Semmama, Serraguia, Sidi Ali ben Aoun, Sidi Aich, Kef Cehala, Oum Debane, Majoura, Bou Hedma, chaînes de Gafsa et du Cherb, dj. Al Aiecha, Chemsi, Berda, etc.

Les études de Ph. Thomas permettent d'y reconnaître au moins deux niveaux, d'ailleurs assez difficiles à séparer paléontologiquement:

1) Cénomanien inférieur à *Cyprina cordata, Arca Moutoniana, A. Thevestensis, Cardium incertum, Crassatella Baudeti, Chlamys Desvauxi, C. subacutus, Plicatula Reynesi, Ostrea Syphax, O. Olisiponensis, D. Delettrei, O. flabellata, Holectypus cenomanensis.*

2) Cénomanien supérieur dans lequel on distingue:

   a) un niveau à *Thomasinella punica* avec *Pterocera cerata, Nerinea bicatenata, Radiolites Lefebvrei, Ichthyosarcolites triangularis, Ostrea suborbiculata, O. Olisiponensis, O. cameleo, Hemiaster batnensis, Polytremacis Chalmasi.*

   b) un dernier niveau à *Pecten quinque-costatus, Micropedina Olisiponensis, Nerinea bicatenata, Sphaerulites Biskarensis, Ampullina bulbiformis, Cyprina Barroisi.*

Dans l'Extrême-Sud, la crête septentrionale du dj. Tebaga (région des Chotts), une partie du plateau des Matmata et la grande falaise du Dahar sont sénomaniennes. ([17], [14], [25]). La constitution statigraphique varie peu: à la base, marnes, plus ou moins gypseuses, alternant avec quelques bancs calcaires; en haut, prédominance des calcaires plus ou moins dolomitiques, accompagnés de quelques bancs de grès. Les fossiles y sont beaucoup plus rares et moins variés que dans le Sud, les principales espèces connues sont des Ostracés (*Ostrea flabellata, O. Delettrei*), des Rudistes (*Ichthyosarcolites triangularis*), des Lamellibranches peu caractéristiques (*Corbula* sp., *Mytilus* sp., *Pholadomya Vignesi*) un Gastropode (*Strombus incertus*), des Bryozoaires (*Globulipora africana*).

Le *Turonien* est mal différencié en Tunisie septentrionale. Il paraît être compris dans les assises calcaires non fossilifères qui terminent le Cénomanien.

Cependant au djebel Mokta, à l'Est d'Hammam-Lif, on peut rapporter avec certitude à cet étage quatre groupes de gros rochers, constitués par des calcaires construits et se présentant sous forme de récifs, au dessus de marnes gargasiennes. Ces calcaires récifaux, ont fourni la faune suivante qui est nettement turonienne (?): *Eoradiolites lyratus, Biradiolites lumbricalis, Chondrodonta Joannae, Vola Lapparenti, V. Dutrugei* var. *Beirensis, Nerinea olisiponensis.*

Par contre, dans le Centre (Mrhila, Semmama, Bireno, Ain es Settara, Bou el Haneche, Ayata, Kalaat es Snam, Guern Halfaya, etc.) les travaux

de L. Pervinquière (15) ont fait connaître un Turonien marneux et calcaire possédant une faune caractéristique et très spéciale. Cette faune, qui a été qualifiée de *cryptogène*, ne se rattache ni à celle du Cénomanien ni à celle du Sénonien, surtout en ce qui concerne les espèces d'Ammonoïdés. On y voit des *Pachyceras*, des *Neoptychites*, des *Mammites*, des *Oxynoticeras* qui "n'ont aucun précurseur au Cénomanien et aucun successeur au Sénonien." De plus, certaines de ces curieuses formes (*Pachyceras superstes*, *Oxynoticeras*) rappellent étrangement certaines Ammonites jurassiques.

Cela étant, Pervinquière a distingué deux divisions dans le Turonien de la Tunisie centrale:

1° le Turonien inférieur caractérisé par *Periaster Verneuilli*, *Inoceramus labiatus*, *Neoptychites cephalotus* et *Mammites nodosoïdes* avec *Pachyceras superstes*, *Vascoceras Durandi*, *Oxynoticeras* sp., *Pseudotissotia* sp.

2° le Turonien supérieur caractérisé par *Pachydiscus peramplus* et *Hippurites Requieni*.

C'est avec le Turonien de l'Inde (district Trichinopoly), que le Turonien bathyal de la Tunisie centrale présente le plus d'affinités.

Dans le Sud, la faune du même étage se relie, par beaucoup d'espèces communes ou représentatives, aux faunes cénomanienne et sénonienne. Ph. Thomas (16) pense, à juste titre, que l'apparition de la faune cénomanienne a inauguré une nouvelle phase biologique qui atteint son complet épanouissement pendant le Turonien.

Ce dernier étage se trouve bien représenté dans la chaîne de Fériana, au dj. el Oguef, au dj. Sidi Aïch, au dj. El Ayaïcha, au dj. Taferma, etc.

Le Turonien inférieur est généralement difficilement séparable du Cénomanien supérieur: il se compose aussi de calcaires dolomitiques et de marnes avec de rares fossiles tels que *Radiolites Lefebvrei*, *Ostrea flabellata*, etc. qui existent également dans le Cénomanien.

On trouve, au dessus, une série de marnes ou marno-calcaires blanchâtres, plus ou moins gypseux, avec des calcaires dolomitiques ou gréseux. Les fossiles que l'on y rencontre sont soit particuliers au Turonien soit Cénomaniens soit Sénoniens. Les espèces les plus remarquables de cette faune mixte sont: *Radiolites Lefebvrei*, *Ampullina bulbiformis*, *Cyprina Barroisi*, *Protocardia Hillana*, *Modiola Flichei*, *Astarte Seguenzae*, *Plicatula Ferryi*, *P. Flattersi*, *Ostrea Boucheroni*, *O. Oudrii*, *O. Heinzi*, *Cyphosoma Baylei*, *Goniopygus Peroni*, *Hemiaster Africanus*, *H. obliquetruncatus*, etc.

Généralement, le Turonien se termine par une puissante dalle de calcaire cristallin, blanc à Hippurites.

Dans l'Extrême-Sud, cet étage est présent au djebel Tebaga, au Sud du Chott Fedjedj, dans la falaise des Matmata. Il constitue, enfin, l'abrupt qui

termine la falaise du Dahar et on peut le suivre, vers le Sahara, jusqu'au parallèle de Bir Kecira. Il se présente alors sous forme d'une dalle de calcaire dolomitique ou marmoréen, d'environ 30 mètres d'épaisseur. Les seuls fossiles que l'on y trouve sont des Hippurites, particulièrement abondantes à Bir Kecira.

Les formations du groupe *Néocrétacé* sont abondamment représentées en Tunisie. La mer sénonienne a eu la même extension que la mer mésocrétacée, bien qu'on y observe, cependant, un retrait vers le Nord de la fosse à sédimentation bathyale.

Dans la Tunisie septentrionale, qui appartient tout entière au faciès bathyal, il est possible de distinguer deux régions distinctes correspondant à deux manières d'être différentes du Sénonien.

La première de ces régions est limitée à la zone tunisoise, dans un rayon d'environ 80 kilomètres autour de la capitale de la Régence. Le Néocrétacé n'y est représenté que par le seul étage *Maëstrichtien* qui est discordant sur le Mésocrétacé et est recouvert par l'Eonummulitique supérieur. On observe ses affleurements aux environs de Tunis, au dj. Ahmar, aux dj. Naheli, Sidi Salah, Ben Neja, Nadour, Oust, Fedja, Djerifète, Sidi Mohamed en Nouali, Bou Kournine, à Aïn Akkach, Pont du Fahs, Bou Arada, Gueriat el Atach, etc. Les recherches de l'auteur ([illegible]) ont permis d'y reconnaître deux zones:

1° Zone à *Bostrychoceras polyplocum* caractérisée par l' association d'une faune d'Ammonites pyriteuses dont beaucoup de types proviennent du Maëstrichtien des Valudayoor Beds (Inde) et d'une faune d'Echinides dont les types se retrouvent dans le Maëstrichtien de la Scaglia italienne. Il arrive, fréquemment, surtout dans les environs de Tunis, de noter l'absence des Céphalopodes, tandis que les Echinides sont très nombreux. Au point de vue lithologique, les assises renfermant une telle faune consistent en alternances de marnes et de calcaires, gris ou verdâtres, assez durs et disposés en bancs bien lités.

Les principales espèces fossiles sont: *Bostrychoceras polyplocum, Phylloceras Forbesianum, Puzosia diphylloïdes, P. Gaudama, P. leonis, Tetragonites epigonum, Pachydiscus selbiensis, Hauericeras, Rembda, H. Gardeni, Lytoceras Kayei, Parapachydiscus selbiensis, Homoeaster tunetanus, H. discrepans, Auberti, Rispolia subtrigonata, Ovulaster zignoanus, Auberti, Lambertiaster Douvillei, Echinocorys* sp., *Stenonaster tuberculatus, Hemiaster subverrucosus, Pycnodonta Flicki, Terebra-*

tula Brossardi, Lapeirousia Pervinquieri, Biradiolites cornuvaccinum.

2° Zone à *Parapachydiscus neubergicus* caractérisée par une moindre quantité de types des faunes ammonitiques et échinitiques précédentes et par l'apparition de Gastropodes du Maëstrichtien supérieur de la Perse (Louristan). La constitution lithologique est plus marneuse que dans la zone inférieure; les marnes sont fréquemment gypsifères. Les principaux fossiles sont: *Latidorsella Snamensis, Hauericeras* sp., *Irania granulata, Procerithium Morgani, Campanile Morgani, Natica canaliculata, Thecidea papillata, Terebratulina chrysalis, Biradiolites austinensis, Baculites vertebralis, Isocrinus Peroni,* etc.

La seconde région sénonienne de la Tunisie septentrionale (*faciès tellien* de l'auteur) est développée dans les monts des Hédil, les abords de la Garaet Achkel, les environs de Bizerte, de Mateur et de Béja, les Nefza et la Kroumirie, près de Medjez el Bab, de Slouguia, de Teboursouk, etc., Le Néocrétacé y forme une série complète, en continuité de sédimentation avec le Mésocrétacé, d'une part, et avec le Nummulitique, d'autre part. Les fossiles y sont assez rares; aucun horizon paléontologique n'indique la présence du Maëstrichtien ni du Danien ni d'aucun des étages qui s'échelonnent entre le Campanien et le Londinien, tous ces niveaux étant englobés dans un complexe marneux auquel on a donné le nom assez impropre de *marnes suessoniennes.*

L'étage *Coniacien* n'a été repéré, avec certitude, qu'en un seul point des Hédil (dj. Saf-Saf) où des marnes grises ont fourni *Tissotia Fourneli.*

Le *Santonien* est également très mal défini. Il faut admettre qu'il est représenté, avec le Coniacien, dans le complexe de marnes grises ou bleues qui sont subordonnées au *Campanien.*

Ce dernier étage comprend des calcaires blancs, homogènes, bien lités renfermant des Echinides (*Stegaster altus, S. Bouillei, S. Chalmasi, Entomaster Rousseli*), des Inocérames (*Inoceramus regularis*) et, au Sfaïet Krelas, dans les Hédil, des *Bélemnitelles.* Les Echinides sont caractéristiques du *Campanien supérieur* des Pyrénées.

Dans la Tunisie centrale, L. Pervinquiere ([15]) a, également, reconnu deux faciès du Sénonien, qu'il a nommés *faciès central* et *faciès méridional.*

Les faciès central (Kalaat es Snam, Ayatâ, Guern Halfaya, Koudiat ez Zerga, Dyr el Kef, Maiza, Massouge, Sra Ouertane, Hamadat des Ouled Aoun, Maktar, Sekarna, Barbrou, Rbiba, Trozza, Kessera, Siliana, Selbia) est caractérisé par le développement énorme des marnes bleu cendré, atteignant jusqu'à 300 mètres de puissance. Les étages suivants y ont été reconnus:

1° Le *Coniacien*, horizon à *Plesiaster Peini*.

2° Le *Santonien* (et sans doute une partie du *Campanien*), horizon à Ammonites ferrugineuses, dont la plupart des espèces se retrouvent au même niveau dans l'Inde et au Japon: *Bostrychoceras punicum, Phylloceras Forbesianum, Hauericeras Gardeni, H. Rembda, Gaudryceras Kayei, G. striatum, Tetragonites epigonum, T. Cala, Phylloceras Forbesianum, Puzosia diphylloïdes, P. Gaudama*, etc.

3° Le *Campanien*, surtout calcaire, avec *Entomaster Rousseli, Guettaria Angladei*.

4° Le *Maëstrichtien*, marno-calcaire, avec *Bostrychoceras polyplocum, Prapachydiscus colligatus, Anisoceras* sp., *Inoceramus Cripsii*.

5° Un étage marneux à Crinoïdes et Echinides, faisant partie d'un puissant complexe marneux comparable aux marnes suessoniennes, ci-dessus décrites, et que L. Pervinquiere considère somme représentant le Danien, mais qui est, plus vraisemblablement Maëstrichtien supérieur.

Le faciès méridional (Bireno, Koudiat Sidi Mabrouk, Sif, Bou Driès, Mrhila, Semmama, Tiouacha, Ras Si Ali, Medarga, Thala, Draa et Thaga), est marneux et calcaire. On y observe un mélange de faunes bathyales, représentées par des Céphalopodes, et de faunes néritiques, représentées par des Bivalves, des Echinides et quelques ammonites néritiques à cloisons très peu découpées semblables à celles de Cératites du Trias (*Hemitissotia Morreni, Heterotissotia neoceratites, Tissotia Fourneli, T. Grossouvrei, T. Tissoti*). Ces ammonites spéciales sont localisées dans la zone inférieure du groupe. Les étages distingués sont les suivants:

1° Le *Coniacien* avec les Ammonites cératitiformes précitées, et: *Barroisiceras Haberfellneri, Mortoniceras Emscheris, Peroniceras subtricarinatum, Holectypus turonensis, Hemiaster Fourneli, Ostrea dichotoma*, etc.

2° Le *Santonien* avec *Mortoniceras texanum, Placenticeras syrtale, Nautilus sublaevigatus, Pycnodonta vesicularis, Micraster Heinzi*.

3° Le *Campanien* avec *Entomaster Guettardi, Guettaria Angladei, Mortoniceras delawarense, Prapachydiscus colligatus, Inoceramus Cripsii*.

4° Le *Maëstrichtien* à *Bostrychoceras polyplocum*.

Le *Danien* manque.

Dans le Sud, les affleurements sont nombreux. Malheureusement, les Ammonites y sont rarissimes d'où quasi impossibilité de discerner les divers étages. On peut, cependant, avec Ph. Thomas (1*) distinguer un groupe inférieur correspondant au Coniacien et au Santonien, et un groupe supérieur correspondant au Campanien et au Maëstrichtien. Dans la chaîne de Gafsa, il est, en outre, possible de préciser la succession du Maëstrichtien, du Danien et du Montien.

Le groupe inférieur, marneux et calcaire, est développé dans la chaîne de Fériana, au khanguet Saf-Saf, aux djebels, Goubeul, Gouleb, dans la chaîne de Gafsa, au Koudiat Hamadi, au dj. Mrata, au dj. Blidji, dans les dômes du Berda et d'El Ayeïcha, dans la chaîcha du Cherb. Les fossiles sont très abondants; on y rencontre des Lamellibranches (*Ostrea Boucheroni, O. dichotoma, O. proboscidea, Arca Maresi, Mytilus Charmesi, Cyprina Barroisi*), des Gastropodes (*Pterocera Cotteaui, Turritella disjuncta, Voluta Tissoti*), quelques Ammonites (*Tissotia Peroni*), des Echinides (*Hemiaster Fourneli*) des Bryozoaires (*Flustrina, Ceriopora*), etc.

Le groupe supérieur possède une répartition identique. Sa constitution lithologique est surtout calcaire avec des intercalations marneuses qui sont principalement développées dans le Cherb occidental (dj. Dhroumes), dj. Taferma). Des marnes blanchâtres et des gypses s'y trouvent aussi au djebel Aïdoudi, non loin de la Petite Syrte. Les principaux fossiles sont des Foraminifères) (*Orbitoïdes Tissoti*), des Echinides (*Hemipneustes Delettrei, Opisopneustes Cossoni, Hemiaster Auberti, Salenia nutrix, Pyrina Bleicheri, Bothryolampas tunetanus*) des Lamellibranches spéciaux (*Roudaireia auressensis, Crassatella numidica*), des Ostracés (*Ostrea Villei, O. decussata, O. Matheroni*).

Dans la chaîne de Gafsa, au djebel Zerf, près des exploitations de phosphate de chaux de Metlaoui, on observe, au dessus des calcaires blancs siliceux à Inocérames, vraisemblablement campaniens, une suite d'assises représentant le Maëstrichtien, le Danien et le Montien, et dont les caractères sont les suivants:

1° Maëstrichtien: Marnes noires à *Ostrea ungulata, O. larva* et couche de phosphate de chaux rouge renfermant des dents de *Corax pristodontus*; puis marnes noires à célestite et à *Ostrea Overwegi*.

2° Danien: lumchelle à *Nautilus* cf. *danicus*.

3° Montien: Lumachelle et meulière à Cardites et à débris de Crustacés (*Callianassa*) avec des Echinides (*Bothriolampas tunetanus*).

Dans l'Extrême Sud, le Sénonien existe au dj. Tebaga, au dj. Halouga, sur le plateau du Dahar et des Matmata; il se poursuit jusqu'à la limite

extrême du pays, à travers le Sahara, dans la région de Fort Saint et de Ghadamès.

Au Tebaga (Sud des Chotts), le Sénonien inférieur est marneux avec des Ostracés: *Ostrea Matheroni, Exogyra spinosa.* Le Campanien est formé de calcaires marmoréens renfermant *Orbitoides Tissoti, Ostrea Mermeti, Exogyra Overwegi* (mutation ancienne), *Inoceramus Cripsii.* La partie supérieure de ces calcaires est vraisemblablement maëstrichtienne.

Sur le Dahar, le Sénonien inférieur est représenté par des marnes à *Paragygus Coquandi, Echinobrissus pseudominimus, Hemiaster Fourneli, Aporrhais Cotteaui.* Plus au Sud (dj. Senirher, Khechem Chaab er Retem, etc.), le Campanien, constitué par des marnes plus ou moins gypseuses et des calcaires, renferme *Alectryonia Nicaisei, A. Aucapitainei.* Le Maëstrichtien est surtout calcaire; c'est lui qui, à partir du parallèle du Senirher, occupe le sommet de tous les plateaux tabulaires, dont la surface va en s'inclinant doucement vers le Sud jusque vers la cuvette de Fort Saint. L. Pervinquière y a recueilli un très grand nombre de fossiles, notamment autour de Fort Saint et de Ghadamès (24, 25): *Libycoceras Ismaelis, Baculites anceps, Inoceramus regularis, I. Impressus, Roudaireia Drui, Aporrhais Meslei, Nautilus sublaevigatus, Orbitoides Tissoti, Voluta Bayli, V. stromboides, Exogyra Matheroni, Venus subfaba, Arca Schweinfurthi, A. Schweabenaui, Cardita Beaumonti, Turritella Forgemoli, Astarte Similis,* etc.

La plupart de ces espèces sont connues du Maëstrichtien de Maëstricht et de l'Inde.

Cenozoïque.

Nummulitique.

La mer nummulitique n'a pas dépassé, vers le Sud, la zone synclinale, appelée Bled Segui, qui sépare les dômes du Sehib et du Berda de la chaine du Cherb. Son extension marque donc une sérieuse régression par rapport à la mer sénonienne.

Les bassins profonds continuent à régner sur la Tunisie septentrionale, sur l'emplacement des fosses bathyales du Néocrétacé. Toutefois, sans doute à cause du comblement avancé de ces fosses par les sédiments sénoniens, la mer éocène a été beaucoup moins profonde. Son plafond a continué de se relever au cours de la période nummulitique ainsi qu'en témoignent les changements de faciès.

C'est ainsi que, pendant la durée de l'Eonummulitique et une partie du Mésonummulitique, se sont formés des dépôts assez bathyaux sur la région la plus septentrionale du pays (faciès des calcaires à Globigérines et à Polypiers), des dépôts néritiques dans le Centre (faciès à Nummulites), des dépôts encore plus néritiques et sublittoraux dans le Sud (faciès à Ostracés

et à phosphate de chaux). Pendant la seconde moitié du Mésonummulitique et le Néonummulitique, le faciès à Ostracés remonte dans les régions septentrionales et le faciès à Nummulites remplace le faciès à Globigérines. Conséquemment, un faciès gypseux, probalement lagunaire, s'instaure dans le Sud et même, à la fin de la période, la plus grande partie du Centre et le Sud tout entier présentent les caractères d'une contrée exondée, sur laquelle ont dû s'accumuler des sédiments d'origine continentale dont il ne reste actuellement plus aucune trace.

Sauf en quelques points de la Tunisie septentrionale (Région de Tunis, régions d'Oudna et de Bou Arada), où paraissent s'être fait sentir des *mouvements antélutétiens* et où les calcaires londiniens et lutétiens reposent transgressivement et directement sur le Maëstrichtien, la continuité entre le Sénonien et l'Eocène est absolue. On a indiqué, précédemment, comment le passage entre les deux séries s'effectue par l'intermédiaire d'un complexe argilo-marneux, improprement désigné sous le terme de *marnes suessoniennes*, qui englobe, compréhensivement, le Danien, le Montien et le Thanétien. Cette continuité a été démontrée, récemment, par un sondage de 1540 mètres de profondeur, effectué dans la presqu'île du Cap Bon et qui a recoupé une série complète depuis la base du Londinien jusqu'à l'Aptien.

En Tunisie septentrionale, les "marnes suessoniennes" ont fourni, en quelques rares endroits (Béjaoua), des fossiles de l'Eocène inférieur: *Cardita Mokattamensis, Ostrea eversa.*

Le reste du Nummulitique peut se subdiviser en trois groupes: à la base, un groupe calcaire correspondant à une partie de l'Eonummulitique et à une partie du Mésonummulitique (Londinien-Lutétien); au milieu, un groupe marneux correspondant surtout au Mésonummulitique; en haut, un groupe gréseux correspondant à une partie du Mésonummulitique et au Néonummulitique.

Le groupe intermédiaire est homogène et ne présente pas de variations sensibles de faciès. Par contre, les groupes inférieur et supérieur permettent la distinction de plusieurs faciès. On trouvera, dans le tableau 2 la répartition géographique de ces faciès ainsi que leurs corrélations.

D'une manière résumée, on peut dire que le groupe inférieur présente les 3 faciès suivants (9):

1° *Faciès A néritique profond*, comprenant des calcaires plus ou moins marneux *à Globigérines et Polypiers*, et reposant en concordance sur des marnes "suessoniennes" Sa répartition géographique coïncide avec le "*sillon sud-tellién de* M.M. GIGNOUX.

2° *Faciès B néritique profond à Globigérines et Brachiopodes*, constitué par des calcaires blancs crayeux et reposant, en

discordance, sans interposition des marnes "suessoniennes," sur le maëstrichtien à *Hauericeras Gardeni.*

3° *Faciès C néritique peu profond,* caractérisé par des calcaires cristallins *à Nummulites et à phosphate de chaux,* reposant sur des marnes suessoniennes.

Entre les faciès A et C, on observe, dans le Sud des Hédil, un faciès de transition réunissant les caractères paléontologiques des deux faciès et renfermant de petites couches de phosphate de chaux associées à de la glauconie.

Le groupe supérieur du Nummulitique de la Tunisie septentrionale, on distingue deux faciès:

1° *Faciès A des grès sans nummulites* (Medjanien et Numidien de Ficheur) qui s'étend sur la Kroumirie, les Mekna, les Mogods et les Nefza.

2° *Faciès B des grès à Nummulites.*

En Tunisie centrale, le Nummulitique ne dépasse pas, au Sud, la latitude de Thala et repose toujours en concordance de stratification sur le Néocrétacé. L'assise des "marnes suessoniennes" y est bien développée et on y distingue les deux faciès B et C de la Tunisie septentrionale. La limite entre ces deux faciès est une ligne allant de Souk el Arba, sur la Medjerda, à Kairouan: le faciès à Globigérines et Brachiopodes est situé au Nord-Est de cette ligne, à Ellez, au dj. Massouge, dans la vallée de la Siliana, dans la vallée de l'Oued el Kebir, etc.

Le faciés à Nummulites existe à Kalaat es Snam, à Kalaa Djerda, à Aïn Massa, à Rebiba, au djebel Houd-Kef Slougui, au Guern Halfaya, au Dyr el Kef, à la Sra Ouertane, à Kalaat el Harrat, à la Kalaa des Ouled Aoun, au Sekarna, dans le massif de Maktar, etc. On rencontre, à sa base, audessous des calcaires litétiens à *Nummulites Gizehensis* et *N. Rollandi,* un horizon de phosphate de chaux, probablement londinien, qui est exploité à Kalaa Djerda, Kalaat es Snam et Rebiba. Outre les Nummulites précitées, les fossiles sont rares et consistent surtout en Ostracés (*Ostrea multicosta, O. multilamella*), et en débris de Squalidés.

Le Mésonummulitique est constitué par des calcaires grossiers, des argiles plus ou moins gypseuses et des lumachelles. Ses principaux gisements, relevés par L. PERVINQUIÈRE ([1]) sont: dj. Oosselat, Trozza, Cherichira, Batene, Rebeiba, Barbrou, Ksaïra, Chouchet es Sid, Sekarna, Maktar, Oum Delel, Ayata, Ellez, Massouge, Houd, Dyr el Kef. D'après les travaux du géologue précité, on peut y introduire les coupures suivantes:

1° *Lutétien supérieur*: Calcaires grossiers et marnes à *Ostrea Bogharensis et Thersitea.*

2° *Auversien*: partie supérieure des marnes à *Ostrea Bogharensis*

3° *Bartonien*: Lumachelles à *Ostrea Bogharensis* et *Ostrea Clot-Beyi.*

Le Néonummulitique de la Tunisie centrale est constitué par des alternances de marnes et de grès. On le trouve au Djebil, au Batene, au Cherichira, au Trozza, au Barbrou, à Maktar, au Belouta, à Srasif el Hajem. Il se rattache au faciès B du Néonummulitique de la Tunisie septentrionale. Bien que très fossilifère, il est assez malaisé d'y introduire des coupures stratigraphiques. Cependant, JEAN BOUSSAC (16 bis) a montré l'existence certaine du *Rupélien* dans les couches du Batene et du Cherichira. Ces couches renferment, en effet, outre quelques espèces spéciales (*Echinolampas cherichirensis, Eupatagus Meslei, Peten tunetanus, Pyrula antiqua*), des espèces essentiellement oligocènes, telles que *Scutella striatula, Clypeaster biarritzensis, Pecten arcuatus, Latrunculus Caronis.*(2)

Le Nummulitique du Sud tunisien présente une importance économique exceptionnelle en raison des vastes gisements de phosphate de chaux qu'il recèle. Ces gîtes sont exploités à Metlaoui, Redeyef, Moularès, Mdilla, Meheri Zebbeus.(28)

Le faciès de ce Nummulitique est essentiellement néritique, avec prédominance des Ostracés et des Echinides. Les Nummulites y sont une rareté, bien qu'elles n'en soient cependant pas tout à fait exclues (dj. Blidji). La coupe la plus complète de la série est celle que l'on peut relever au droit de Metlaoui.

Les lumachelles montiennes sont suivies par d'autres lumachelles et des calcaires marneux à *Ostrea multicostata, O. Bellovacina, O. eversa, O. punica, Cerithium tunetanum, C. rediviosum, C. tseldjaticum, Aporrhaïs decoratus, A. chiastus, etc.* qui représentent le *Thanétien* et une partie du *Londinien.*

Puis viennent quatre couches de phosphate (zone industrielle) intercalées de marnes. Elles ont fourni de nombreux débris de Squalidés, des restes de grands reptiles (*Dyrosaurus phosphaticus, Cimoliosaurus,* etc), *Ostrea multicostata, Nautilus* sp.

On trouve, ensuite, des calcaires en gros bancs, des lumachelles épaisses à *Ostrea multicostata*, des marnes phosphatées, puis un horizon siliceux, constitué par des boulets de silex dans lesquels abondent, au djebel Mdilla, *Schizaster Meslei*, Echinide des marnes à *Carolia placunoïdes* et *O. Clot Beyi* de l'*Auversien-Bartonien* de la Tunisie centrale et du Mokattam.

Enfin, la série se termine par des gypses qui peuvent manquer comme, par example, au djebel Mdilla.

On voit que les couches phosphatées sont très vraisemblablemment londiniennes, comme dans le Centre et le Nord, et que les calcaires et les lumachelles, qui leur servent de toit, sont à rapporter au Lutétien et, peut-être, en partie, à l'Auversien.

Au djebel Anik au Sud-Est de Gafsa, le toit de la formation phosphatée est beaucoup plus gypseux que dans la coupe de Metlaoui; l'horizon siliceux manque mais est remplacée par une couche importante (de 0m 50 à 8 mètres) de *minerai de fer oolithique*, intercalée entre une assise de marnes à *Carolia placunoides* et *Ostrea Bogharensis* et une assise marno-calcaire à *Schizaster Meslei*. De nombreux restes de Squalidés se trouvent dans le minerai qui, sur le flanc sud du synclinal de Bou Rhedja, passe à des couches de *chamosite*.

Le Nummulitique du Sud existe dans la zone occidentale de la chaîne de Gafsa (Lousif, Zerf, Tseldja, Blidji, Redeyef, Moularès), au dj. Mrata, au dj. bou Smaïl, autour du dôme d'El Ayaïcha, au Meheri Zebbeus, au Zebbeus Douara, à Aïn Rebaou, au dj. es Souda, aux djebels Sidi Kralif et Nasseur Allah, au dj. Berda-Atra, au dj. Mdilla-Sehib.

Néogène.

La période Néogène est caractérisée par la réduction de l'espace marin, puis par l'instauration d'un régime qui diffère très peu de l'état actuel de la Méditerranée.

Dès la fin du Néonummulitique, des mouvements épirogéniques font émerger toute la région des grès de Kroumirie. Une exondation de toute la région située au Sud-Est d'une ligne joignant Kairouan au djebel Goubel (frontière algérienne) se produit aussi. La mer burdigalienne occupe le couloir laissé entre les deux blocs exondés et passe en Algérie.

Au Vindobonien, le bloc méridional, seul, s'affaisse de nouveau tandisque le bloc Kroumir demeure exondé; une mer peu profonde s'avance transgressivement vers le Sud mais elle dépasse pas le parallèle d'Henchir Souatir, au Nord du massif de Gafsa. On ignore quel était le tracé exact du rivage méridional de cette mer; il est probable qu'elle recouvrait tout le Sahel puisque des dépôts vindoboniens existent aux environs de Sousse (Monastir, Djemmal). Elle devait aussi former, dans l'Extrême-Sud, un vaste golfe sur l'emplacement d'une partie de la Djefara actuelle et sur celui de l'île de Djerba: tous les forages artésiens de cette contrée ont, en effet, recoupé les couches de lignite par lesquelles se termine le Vindobonien et l'un d'eux, à Ben Gardane, a remonté, d'une profondeur supérieure à 200 mètres, de nombreux exemplaires d'*Ostrea crassissima*. Dans l'état actuel des choses, aucun affleurement néogène n'est visible dans l'Extrême-Sud où tout est recouvert par un manteau épais de sédiments pleistocènes.

Il est probable qu'une phase saumâtre ou lagunaire, synchronique du Sarmatien, a terminé le Vindobonien comme l'attestant les dépôts de lignites de Monastir, de Djemmal, de Djebibina et du Cap Bon, où les strates charbonneuses sont accompagnées d'une faune de Potamides

Au Sahélien-Pontien, la mer s'est presque complètement retirée de la Tunisie: elle forme seulement quelques indentations le long du littoral septentrional actuel, sur les emplacements des lacs de Bizerte et de la plaine de la basse Medjerda.

Par, contre, les formations continentales de cette époque sont abondamment développées; un régime de lacs d'eau douce s'est instauré sur le bloc Kroumir et aux environs, tandis que, dans le reste du pays et dans le Sud, se sont formés de véritables *chotts* dans lesquels se déversent de vastes cours d'eau.

Le même état de choses subsiste, au point de vue des formations continentales, pendant le Pliocène: de plus, les grands golfes sahéliens du Nord ont disparu et ont fait place à des lacs d'eau douce ou saumâtre (dépôts à *Mastodon arvernensis* de Ferryville, à *Hipparion crassum* et *Hippopotames* d'Utique et de Tunis). La mer pliocène paraît n'avoir pénétré la Tunisie que sur une largeur très restreinte du littoral oriental actuel, entre Kelibia, dans la presqu'île du Cap Bon, et le Ras Kaboudia. Au Sud de ce dernier point, le Pliocène marin est inconnu.

On ignore aussi ce que pouvait être le tracé de la mer du Néogène supérieur, au Nord de la côte septentrionale actuelle. Il passait peut-être quelque part entre la Sicile et la Tunisie; mais, si l'on considère que le Pliocène marin fait aussi défaut dans le Sud de la Sicile, on ne peut se défendre d'émettre l'hypothèse qu'un *pont* continental pouvait unir la grande île Italienne à la Tunisie, pendant les temps du Néogène supérieur.(9)

On trouvera, dans ce qui suit, l'énumération des principaux affleurements néogènes de Tunisie avec leurs caractéristiques.

Le *Burdigalien* se présente sous des aspects analogues en Tunisie septentrionale et en Tunisie centrale: marnes et grès assez grossiers ou calcaires (Cap Bon, voir 8 bis). On le trouve, en Tunisie septentrionale dans les localités suivantes: Cap Bon, Henchir Rarounkel, Henchir Bordj Chellouf, dj. Mellaha et Hakima, El Arima, Sidi el Alidj, djebels Anz, en Nechma, Lanserine, en Naga (Béja) Munchar, el Haouaria, Henchir Haroun, Argoub Zateur, Pont de Trajan, Fedj el Adoum, etc. En Tunisie centrale, il faut citer: Cherichira, Batene, Trozza, Abeïd, Mrhila, Semmama, Bled Zelfane, Saadine, Guern Halfaya, Zafrane.

Les fossiles appartiennent presque toujours au Burdigalien moyen de la vallée du Rhône; ce sont, notamment: *Scutella subrotunda*, *Amphiope* sp., *Echinolampas pyguroïdes*, *Clypeaster intermedius*, *Pecten convexior*, *P. proescabriusculus*, *P. sub-Holgeri*, *P. Fuchsi*, *P. Crestensis*, *P. benedictus*, *P. Tournali*, *P. tauroperstriatus*, *P. Kochi*, *Turritella terebralis*, *T. turris*, *T. tricincta*, *Cytherea rudis*, *C. pedemontana*, *Trachycardium gallicum*, *Mathilda quadricostata*, *Ostrea Offtreti*, *O. gingensis*.

Le *Vindobonien* débute par des marnes bleues à *Globigérines*, gypseuses et que l'on attribue au sous-étage *Helvétien*. Il se termine par des alternances de marnes, de grès et d'argiles rapportées au *Tortonien*.

On rencontre cet étage dans les localités suivantes:

Tunisie septentrionale: région de Porto-Farina, dj. Kechabta, dj. Sfaïa, Sidi ed Dekounia, dj. Terguellache, dj. Sakkak, dj. Messétetine, dj. Mellaha, Sidi Bou Saïd, Marsa, Megrine, Radès, Cap Bon, Sainte Marie du Zit, Slouguia, Oued Ermoucha, Pont de Trajan, Djebel Cheïd.

Tunisie centrale: Cherichira, Trozza, Abeïd, Mrhila, Zaafrane, Saadine, Guern Halfaya, Djerfen.

Tunisie méridionale: Henchir Souatir.

Les fossiles sont peu nombreux. De l'Helvétien, on peut citer: *Pecten Fuchsi, P. Gentoni, Scutella Bleicheri, Amphiope cherichirensis Ostrea aginensis, O. digitalina, Venus fasciata, Arca clathrata.*

Le Tortonien est caractérisé par la grande fréquence de l'*Ostrea crassissima*, dont certains exemplaires atteignent parfois une taille énorme. On y trouve encore: *Ostrea digitalina, O. Velaini, Lithodomus.*

Il se termine, en certains points, par des couches renfermant des dépôts continentaux ou laguno-saumâtres. C'es ainsi qu'au djebel Cherichira, on a trouvé dans les dernières couches du Tortonien une tête de *Mastodon angustidens.*

Au Cap Bon [*], à Monastir, à Djemmal et à Djemmal et à Djebibina, ce sous-étage finit par des couches de lignites englobés dans des grès feuilletés et des argiles à *Potamides lignitarius.*

Il est hors de doute que ces couches sub-continentales et laguno-saumâtres ne soient l'équivalent de l'étage *Sarmatien.*

Ainsi qu'il a été dit antérieurement, le *Sabélien* est localisé dans les régions des lacs de Bizerte et des plaines de la basse Medjerda. On y distingue un horizon inférieur, formé de calcaires gypseux puis de marnes bleues, et un horizon supérieur, constitué par des grès mollassiques et des sables. La faune fossile, très abondante, comprend un mélange d'espèces vindobonienne (*Ostrea digitalina, O. gingensis, O. Maresi, O. Velaini, O. fimbriata, Cardita intermedia, Turritella vermicularis, Natica redemptoaurelia, Conus subacuminatus, Nassa albucianensis, Ptychocerithium granulinum, Clavatula rugata, Pleurotoma coronata, P. Jouannetti, Drillia crebristriata, Neritina picta, Melania tuberculata* var. *granulosa, Melanopsis narzolina* var. *agatensis, Ficula condita, Pecten Zitteli, P. solarium*), d'espèces à la fois miocènes et piocènes (*Melania etrusca, Dentalium vitreum, Murex torularius, Turritella subangulata, Cytherea pedemontana*) et de mutations intermédiaires entre des types miocènes et pliocènes (*Flabellipecten sabeliensis* intermédiaire entre *F. Almerai* du Vindobonien et *F. Bosniaskii* du Pliocène, *Flabellipecten* intermédiaire entre *F. Alessii*

du Pliocène et *F. flabelliformis* type du Tortonien de Santa Agata, *Pecten* intermédiaire entre *P. Grayi* du Vindobonien et *P. Jacoboeus* du Pliocène, etc.)

Le *Pontien lacustre* de la Tunisie septentrionale est représenté par des conglomérats et des travertins à *Helix fossulata*, à Djalta, Argoub el Mriss, à Ragoubet el Figel, dans les environs d'Aïn Draham.

Le *Pontien chotteux* et détritique est formé d'argiles latéritiques, de grès et de sables rubigineux renfermant des bois fossiles de *Monocotylédones*. On le trouve, en Tunisie septentrionale à Fedj el Adoum, à Slouguia, à Sidi bou Saïd, le long de la route de la Laverie à Sainte Marie du Zit.

Dans la Tunisie centrale, il a été longtemps confondu avec le Pliocène. Mais, en 1910, L. PERVINQUIÈRE a reconnu que la plus grande partie des formations, qu'il avait décrites sous cette dernière étiquette devaient, en réalité, être attribuées au Pontien ([15] bis): c'est ainsi que les sables rubigineux de Pichon, précédemment considérés comme Néogène supérieur, ont fourni, depuis, à l'auteur des molaires de *Mastodon longirostris*, espèce éminemment pontienne.

Dans le Sud, le Pontien règne autour de toutes les chaînes de montagnes; il se développe aussi dans les plaines synclinales qui séparent les divers massifs entre eux. On le trouve encore, bordant le rivage Nord du Chott el Djerid, entre Nefta et le pied du djebel Taferma; c'est lui qui remblaie, aussi, la cuvette du Nefzaoua et celle d'El Hamma de Gabès. Enfin, il forme une bande, longue d'environ 50 kilomètres de longueur, qui suit le rivage du golfe de Gabès, depuis la Skirra jusqu'aux environs de Médenine.

Cet étage est constitué par une énorme épaisseur de sables et de grès tendres, surmontés par une non moins considérable épaisseur d'argiles rouges, vertes ou grises. Il a une importance économique considérable par le fait qu'il contient une nappe d'eau artésienne à laquelle s'alimentent tous les puits jaillissants du Djerid, du Nefzaoua, et de l'Aradh.

Au point de vue paléontologique, l'horizon sableux inférieur contient de nombreux restes de Vertébrés, qui ont été étudiés par M. M. BOULE et qui représentent des types du Pontien de Pikermi, de Cucuron et des Siwaliks ([19]): *Merycopotamus* cf. *dissimilis*, *Crocodilus sivalensis*, *Hemitragus perimensis*, etc.

Les bois fossiles y sont également très fréquents; leur flore est à peu près la même que celle de la forêt pétrifiée du Caire: *Araucarioxylon aegyptiacum*, *Nicolia aegyptiaca*, *Acacioxylon antiquum*, *Bambusites Thomasi*, etc.

Les argiles de l'Horizon supérieur renferment *Helix Tissoti* qui est un bon fossile du Pontien d'Algérie.

Le *Néogène supérieur marin* n'existe que le long du littoral oriental du Cap Bon ([6]), à Sousse, Monastir et aux environs de Mahdia. Les faciès plaisancien et astien s'y pénètrent intimément. Cependant M. Allemand-Martin y distingue un horizon inférieur (marnes bleues ou marnes à *Pecten cristatus*, *P. latissimus*) et un horizon supérieur (sables et grès jaunes à *Pecten Jacoboeus*, *P. flabelliformis*, *P. varius*, *Echinolampas Hoffmanni*, etc.)

Enfin, le même auteur a signalé, au dessus des couches précédentes, dans les environs d'Hammamet et de Nabeul, un niveau de grès grossiers, avec *Pecten Jacoboeus*, *Cerithium vulgatum*, *Cardium edule*, qu'en raison de leur altitude (8 à 60 mètres), il attribue à l'étage *Calabrien*.

Le Pliocène continental est développé, en Tunisie septentrionale, dans les régions de Bizerte (Ferryville), de Tunis (Menzel R'oul, Belvédère, Ariana, dj. Aïn el Krima), de Medjez el Bab, Bou Arada, Zaghouan, Béja, Oued Zerga, Testour.

A Ferryville, il est constitué par des argiles à *Ostrea cochlear* surmontées de sables à *Mastodon arvernensis*. Partout ailleurs, il est formé d'argiles à *Helix Constantinae* alternant avec des sables et des grès, souvent en masses lenticulaires, dans lesquels on trouve des débris d'*Hipparion crassum*, *Hippopotamus*, etc.

En Tunisie centrale, le Pliocène continental mérite une nouvel-révision depuis la réserve formulée par Pervinquière au sujet de la nécessité de classer dans le Pontien la plupart des affleurements déterminés, antérieurement, par lui comme Néogène supérieur.

Dans le Sahel, le Pliocène du plateau d'El Djem rappelle celui du Belvédère de Tunis et n'a jamais encore fourni de fossiles.

Pleistocène.

Les formations pleistocènes sont abondamment dévelloppées dans toute la Tunisie. On y distingue des couches marines, laguno-saumâtres et continentales. Ces dernières possèdent une extension géographique considérable, principalement dans la vaste région de plateaux et de plaines qui s'étend en arrière des Sahels de Sousse et de Sfax, dans les plaines du Sud et de l'Extrême Sud. Elles sont' d'ailleurs, presque absolument inconnues au point de vue stratigraphiques, leur étude n'ayant jamais été abordée sérieusement.

On se rend compte, par cela même, de l'inanité des tentives de synthèse du Quaternaire tunisien. La seule indication géologique que nous avons sur elles, c'est que, dans la région de Redeyef, et de Gafsa, au dessus de cailloutis ou de conglomérats grossiers renfermant des silex taillés du type chelleen, on trouve des sables, plus ou moins argileux contenant des

Hélicidés, du groupe d'*Helix melanostoma*, associés à des restes de *Rhinoceros tichorinus* ([23] bis).

La stratigraphie des formations marines, littorales ou sublittorales, est un peu mieux connue grâce aux travaux de L. Pervinquiere ([16]), de Mm. Allemand-Martin ([7]), L. Joleaud ([17]), Seurat ([29]), et Larroque.([30]).

La formation pleistocène la plus ancienne, correspondant à l'étage Sicilien, n'est réellement bien déterminable que dans la région de Bizerte, où l'auteur a signalé ([9]) une panchina, très peu riche en fossiles marins, mais dans laquelle des restes d'un Buffle du Pleistocène ancien de l'Inde, *Buffelus palaeindicus*, associés à un Gastropode terrestre éteint, *Xerophila Milsomi*. C'est également au Sicilien que l'auteur attribue, actuellement, des argiles noires, saumâtres à *Cardium edule*, qu'il avait primitivement considérées comme représentant l'étage *Milazzien* de Depéret, et que l'on rencontre, à des altitudes diverses, pouvant dépasser 60 mètres, dans la plaine de la Basse-Medjerda.

Le *Pleistocène marin* est surtout développé le long de la côte orientale, depuis Kelibia, dans la presqu'île du Cap-Bon, jusqu'à la frontière tuniso-tripolitaine. C'est surtout dans les régions entourant la Petite Syrte que l'on peut en obtenir la meilleure coupe. En rapprochant les travaux de M. Seurat et de M. Larroque, on peut observer la succession suivante aux Kerkennah, à la Skirra et à Djerba:

1° Quaternaire ancien: Marnes gypseuses.
Travertins à *Archelix constantinae* et *Albea candidissima*.
Poudingues fluviatiles à *Xerophila Mocquerysi*.

2° Quaternaire récent: Poudingue gréso-calcaire à *Mactra Largillierti, Ostrea tarentina*, etc.
Calcaire gréseux blanc à *Strombus bubonius*.
Sable marneux à Hélicidés terrestres actuels.
Dunes consolidées à *Xerophila psammathea*.

La présence de *Strombus bubonius* indique un niveau contemporain des formations, dites *Tyrrhéniennes*, de l'Italie méridionale, décrites par M. le Professeur M. Gignoux. Il semble tout à fait inexact d'admettre que ce fossile puisse se trouver dans l'*étage Tyrrhénien* et dans un étage plus récent, appelé *Monastirien par* Ch. Deperet. Il est, en effet, facile de constater, à Monastir même, localité tunisienne qui a donné son nom à l'étage Monastirien, qu'il y a parfaite continuité entre les dépôts à Strombes placés dans le Tyrrhénien et les dépôts à Strombes considérés comme Monastiriens: cela peut se suivre dans les nombreux puits creusés sur le plateau de la dite localité. L'auteur croit devoir à la mémoire de son regretté Maître, Charles Deperet, de dire que, peu de temps avant la mort

de ce savant, il l'avait convaincu de l'inexistence du Monastirien à Monastir et que la mort a empêché la réalisation d'un voyage en Tunisie au cours duquel cette question devait être examinée en commun.

Pour en revenir à la coupe du Pleistocène de la Petite Syrte elle montre qu'antérieurement au Tyrrhénien, la région s'était progressivement exondée; qu'au Tyrrhénien s'était ouverte une nouvelle phase marine et que la mer n'avait pas recouvert alors la totalité de l'île de Djerba, dans le centre de laquelle le travertin continental est resté exondé; enfin, que, postérieurement au Tyrrhénien, l'exondation a repris pour aboutir à la phase actuelle.

Les grès calcaires blancs à Strombes sont la formation la plus constante et la plus caractéristique du Pleistocène moyen de la côte orientale de la Tunisie. On les retrouve à Sfax, entre Mahdia et Ksour Essaf, à Krnis, à Monastir, près de Sousse, à Hergla, entre Bou Ficha et Hammamet, à Nabeul, à Menzel Temime, près de Kelibia. Au Cap-Bon, ils sont surmontés de la même formation de dunes consolidées qui termine la coupe de la Petite Syrte.

Roches Ignées.

Les roches ignées ne se rencontrent que dans l'archipel de la Galite et dans la Mogodie, c'est dire dans les régions les plus septentrionales du pays. Elles appartiennent à la province des roches calco-sodiques.

Les roches galitoises sont du type abyssique: ce sont surtout des *granodiorites* et des *akérites*, traversées par des filons ou des necks d'autres roches de type hypoabyssique (*microgranites alcalins, microgranite monzonitique, microgranodiorite, diorite-gabbro, aplites*).

Les granodiorites sont recouvertes de marnes calcaires et grès néonummulitiques (faciès A); la base de cette formation sédimentaire est métamorphisée en *cornéennes pyroxéniques* et en *schistes à minéraux*.(*).

En Mogodie, on retrouve les équivalents d'épanchement de roches de La Galite. Ce sont des roches allant de la famille des rhyolites à celle des basaltes: *Delléniles, Dacites, Dacitoide oligoclasique, Labradorite augitique, Basalte β labradorique, Microakérite*.

Toutes ces roches percent au milieu des grès de Kroumirie (faciès A du Néonummulitique) sous forme de cheminées, de bosses ou de dykes

Aussi bien qu'à la Galite, elles sont postérieures au Néonummulitique, et sont, pour la plupart, d'âge vindobonien, comme le montre le tableau 3 dans lequel on trouvera, en outre, les paramètres magmatiques des roches ignées du Nord de la Tunisie et leur distribution géographique.

II. Aperçu Tectonique.

Les schistes et quartzites paléozoiques du djebel Hairech ont une extension géographique insuffisante pour nous renseigner, d'une manière

satisfaisante, sur l'allure générale des plissements qui les ont affectés, antérieurement au mouvement alpin qui les a ployés en dôme. On constate seulement qu'ils sont plissés, que leurs plis sont en dysharmonie profonde avec les plis environnants de la phase alpine, mais on ne sait pas dire à quelle époque ils ont été plissés, sinon qu'ils l'ont été antérieurement au Trias.

Il est également très problématique qu'il y ait pu avoir un mouvement post-triasique, correspondant à la lacune de l'Infralias: nous avons vu, en effet, que la stratigraphie de cette partie du Jurassique est encore incertaine par suite du manque de fossiles. Il en est de même entre l'Aalénien et l'Argovien, où l'on peut se demander si la lacune constatée n'est pas plutôt le fait d'une ignorance partielle et d'une interprétation inexacte de la stratigraphie des couches sans fossiles, peu épaisses en vérité, qui font suite aux derniers horizons paléontologiques reconnus. C'est aussi l'explication admisible pour l'explication de la lacune qui existe entre le Lias et le Bathonien, dans l'Extrême-Sud.

L'époque mésozoïque a été, pour toute la Tunisie, une ère de sédimentation calme et c'est seulement à l'époque tertiaire que l'orogénèse s'est dessinée et réalisée.

Lorsqu'on examine une carte géologique de la Tunisie, on est frappé du fait que la densité superficielle et l'intensité des plissements va en décroissant du Nord vers le Sud. La Tunisie septentrionale est une zone de plis nombreux et serrés, la Tunisie centrale et méridionale une zone d'architecture plus lâche, la Tunisie de l'Extrême Sud une zone aux plis dont les rayons de courbure sont si grands qu'on peut l'assimiler à une région tabulaire.

Il reste, il est vrai, l'énigme de toute la Tunisie orientale, recouverte par des sédiments récents, continentaux, pliocènes et pleistocènes, qui paraissent suivre de grandes ondulations profondes mais dont on ignore la tectonique du substratum. C'est seulement dans la presqu'île de Monastir qu'affleurent des terrains vindoboniens, paraissant dessiner des plis isoclinaux arasés en pénéplaine. Mais, ici encore, le peu d'étendue de la zone observable ne permet pas d'inférer du particulier au général pour l'ensemble du pays oriental.

En raison de sa complexité apparente, la tectonique de la Tunisie septentrionale a donné lieu, de bonne heure, à des théories compliquées. Les nappes de charriage qu'on avait cru y voir n'ont pas résisté à l'examen stratigraphique. Elles étaient nées des anomalies de situation que présentent presque tous les affleurements triasiques, à une époque où la tectonique, si spéciale, des dômes de sel était inconnue.

Plus récemment, en 1927, frappés par l'étrange aspect du djebel Ichkeul, dont les couches jurassiques et crétacées offrent un faciès tout différent de ce qui existe ailleurs, en Tunisie, dans les mêmes étages,

M. P. Termier et l'auteur avaient pensé que cette montagne pouvait représenter un témoin d'une *Tunisie profonde* sur laquelle se serait étalée une nappe faite de toute la série sédimentaire normale, depuis le Trias jusqu'au Vindobonien.

L'année suivante, une novelle visite de l'Ichkeul les convaincait que le faciès particulier du Mésozoïque, en ce point, est un effet d'ordre chimique et que, cela étant admis, l'Ichkeul ne peut plus prétendre au droit d'être l'autochtone d'une nappe de recouvrement.

Il semble donc que l'ère des grands charriages soit définitivement révolue pour la Tunisie.

On distingue, en Tunisie septentrionale les zones tectoniques suivantes (°):

La *zone des grès de Kroumirie,* formée de plis provenant de l'Atlas tellien d'Algérie. Ces plis traversent la frontière suivant une direction Ouest-Est et s'incurvent, ensuite, vers le Nord ou le Nord-Nord-Est. Ils paraissent constituer l'auréole tertiaire de la vaste amygdale hercynienne à laquelle apartiennent les terrains cristallophylliens des Kabylies et du massif de l'Edough, en Algérie. Ils se sont développés sur une région qui est restée exondée depuis la fin du Néonummulitique et qui s'est même un peu déplacée, tangentiellement, sur son substratum Eo- et Mésonummulitique, qu'en certains endroits (col de Babouche, Ain Draham), elle a laminé et écrasé. Il semble que ce petit charriage soit contemporain de la phase d'exondation.

2° La *zone des plis isoclinaux,* de direction NN-SSO, auxquels participent tous les terrains compris entre le Trias et le Vindobonien et qui ont dû commencer de se former dès le Burdigalien supérieur ou l'Helvétien.

3° La *zone des dômes* qui comprend tout le reste de la Tunisie septentrinolae. Ces dômes sont alignés suivant des lignes dirigées NNE-SSO, ils sont généralement complexes et assez serrés (Monts de Zeugitane).

Partout, mais surtout dans les deux premières zones, on trouve de nombreux affleurements de Trias qui occupent des coeurs d'anticlinaux ou qui se présentent sous la forme d'intrusions au milieu des couches plus récentes. Ces anomalies s'expliquent, à l'heure actuelle par les propriétés migratrices, universellement constatées, des terrains salifères, au nombre desquels se trouve le Trias nord-africain.

La Tunisie centrale et la Tunisie méridionale sont aussi des pays de dômes disposés en alignements NNE-SSO ou NE-SO, interférant avec des cuvettes pareillement orientées. Les alignements les plus septentrionaux de la Tunisie centrale sont des virgations d'alignements de la Tunisie septentrionale (Dorsale Tunisienne se ramifiant en quatre chaînes).

Tous ces plis, de même, d'ailleurs, que les plis isoclinaux et les dômes de la Tunisie septentrionale, sont dans le prolongement de directions issues de l'Atlas Saharien d'Algérie. Il est à remarquer qu'entre ces plis de l'Atlas Saharien et ceux de la zone des grès de Kroumirie, qui représentent le Tell, il n'y a pas place, en Tunisie, pour la zone de hautes plaines qui est largement développée dans la colonie voisine et connue sous le nom de Hauts Plateaux ou Haut-Pays.

Les dômes et les plis de la Tunisie centrale et méridionale sont séparés de la Tunisie orientale, pliocène et pleistocène, par un axe de plissement Nord-Sud (dj. Zebbeus, dj. Nasseur Allah, dj. Sidi Kralif) sur l'allure duquel aucune explication valable n'a encore été donnée.

Il convient de signaler aussi la direction Ouest-Est de certaines chaînes du Sud, par exemple la chaîne du Cherb, au Nord des Chotts: mais, dans ce cas, la dite direction est un résultat du modelé topographique car la chaîne se compose d'un grand nombre de dômes, orientés, individuellement, NE-SO et séparés, les uns des autres, par d'étroites gouttières synclinales de même direction.

On a vu, précédemment, que la mer nummulitique n'avait pas atteint la région des grands Chotts. Tout le pays, comprenant la chaîne du Cherb et la contrée qui lui fait suite au Sud, a commencé de s'exonder dès la fin du Crétacé, et ce mouvement s'est accentué, en se développant vers le Nord, jusqu'à atteindre son maximum à la fin du Néonummulitique.

Mais la grande phase de plissement, aussi bien pour la Tunisie du Sud et de l'Extrême-Sud que pour le reste de la Tunisie, est immédiatement postérieure au Pontien. Partout, les formations saheliennes et pontiennes, ont été affectée par elle, alors que les dépôts du pliocène ont restés horizontaux.

Dans l'Extrême-Sud tunisien, les dômes, également d'âge post-pontien, atteignent, en superficie, des dimensions immenses: tels sont le dôme sur l'emplacement duquel s'est creusée la cuvette du Chott el Fedjedj, et le dôme de la Djefara qui plonge, périclinalement, sous la cuvette ensablée du Bas Sahara.

Ce dernier a des dimensions particulièrement imposantes, environ 300 kilomètres mesurés le long du grand axe, entre Gabès, en Tunisie, et Homs, en Tripolitaine. Une grande partie est effondrée sous les eaux de la petite Syrte, sans qu'on puisse préciser l'âge de cet accident. Sur le pourtour, on observe, en forme de pustules de petites dimensions, d'autres dômes, tels que le djebel Tadjera et le djebel Tebaga, près de Médenine.

En résumé, comme l'a déja écrit M. P. Termier, la Tunisie est essentiellement un pays de dômes, et, si l'on considère que le Trias salifère est toujours à l'intérieur de ces dômes, ou, à cause de sa tectonique propre, extravasé à leur voisinage, on peut ajouter que la Tunisie est surtout un pays de dômes de sel. "Toutes les singularités tectoniques de la Tunisie

plissée s'expliquent sans peine dès que l'on admet cette prémisse. Il ne reste plus que des complications locales, qui peuvent être extrêmes, mais qui ne troublent pas l'harmonie générale du plissement tertiaire dans le vaste pays tunisien." [14]

Les mouvements du sol de la Tunisie pendant le Pleistocène sont seulement d'ordre épirogénique. Leurs effets sont surtout visibles le long du littoral de la côte orientale, depuis les îles Kerkennah jusqu'à la frontière tunisco-tripolitaine. Le rivage s'y trouve prolongé, sous la mer, par des hauts fonds immergés à des profondeurs variant de 2 à 30 mètres, et entrecoupés de canaux qui sont, pour la plupart, dans le prolongement des oueds actuels. D'après ce que l'on sait du Quaternaire de la Petite Syrte, il est vraisemblable de placer l'affaissement du littoral primitif à l'époque de la transgression de la mer du Tyrrhénien.

L'auteur pense que c'est à la même époque qu'a cessé la communication de la mer Méditerranée avec la longue dépression des grands Chotts algériens et Tunisiens. Par le jeu de captures antérieures, ces Chotts se trouvaient constituer l'embouchure d'un vaste fleuve saharien, l'oued Igharghar, descendu des hauteurs de l'Ahaggar, et qui n'est plus, maintenant, qu'un fleuve "en léthargie." Cet oued immense était donc tributaire de la Méditerranée pré-tyrrhénienne; il en a été séparé par l'effondrement tyrrhénien qui parait, toutefois, n'avoir affecté que la zone littorale et une certaine partie du cours inférieur de l'Oued, celle correspondant aux emplacements des chotts Rharsa, Melrhir. Le bloc des Chotts el Djerid et el Fedjedj est resté en surélévation (altitude actuelle: + 18 à + 23 mètres) tandisque l'emplacement des autres chotts précités s'est effondré (altitude actuelle:— 7 à— 31 mètres).

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66. ESTUDIO DE PROSPECCIÓN GEOFÍSICA EN ALCALA DE HENARES (SPAIN) FOR EL METODO SÍSMICO

POR

Dr. Ing. José G. Siñeriz,

Ingeniero Jefe de la Sección de Geofísica del Instituto Geológico y Minero de España.

Abstract.

La ciudad de Alcala de Henares se encuentra en el centro de una cuenca de calizas cretacicas, rellena de sedimentos terciarios, que la oculta por completo, a excepcion de sus afloramientos, que la rodean y delimitan, en un gran circulo cuyo diametro es de unos 100 Km. El estudio geológico de la cuenca, hizo suponer que pudiera contener aguas artesianas, en cantidad bastante para surtir a la ciudad antes mencioncida.

Con objeto de conocer de antemano la profundidad probable del sondeo necessario, hemos efectuado un perfil sísmico, desde alcala de Henares a Zorrelaguna, de una longitud aproximada de 50 Km.

El estudio se detalla en el Cap. XVIII, pags. 305-314, de mi obra.

"Los Métodos gofísicos de prospección" asi como los resultados obtenidos.

67 INVESTIGACIÓN GEOFÍSICA EN LA CUENCA CARBONÍFERA DE VILLANUEVA DE LAS MINAS (SPAIN)

POR

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Ingeniero Jefe de la Sección de Geofísica del Instituto Geológico y Minero de España.

ABSTRACT.

Hace un año proximamente, el Instituto Geológico y Minero de Epaña, ha efectuado bajo mi dirección, un estudio geofísico de la cuenca carbonífera de Villanueva de las Minas, cuya prolongación era completamente disconocida, a pesar de haber efectuado hasta nuevos sondeos, alguno de los cuales alcanzó la profundidad de 900 m. El estudio se ha efectuado por los métodos: electrico de corriente continua, gravimétrico, magnetico y sísmico.

En cada uno de ellos, se tomaron todas las medidas necesarias para llegar á obtener una interpretación del problema. La interpretación de conjunto, dada por el Señor SIÑERIZ, ha obtenido completo éxito. Un sondeo mecánico, ejecutado en el punto marcado por el Señor SIÑERIZ, ha cortado cinco capas de hulla de muy buena calidad, que permiten asignar á la cuenca carbonífera, hasta hoy desconocida, una cubicación minima de 10,000,000 Toneladas. Todas las mediciones efectuadas se describen minuciosamente en la Sexta Parte de su obra "Los Métodos Geofísicos de Prospeccion" desle la página 427 á la 488.

68. ESTUDIO GEOFÍSICO PRÉVIO DE LA FALLA DEL GUADALQUIVER

POR

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Ingeniero Jefe de la Sección de Geofísica del Instituto Geológico y Minero de España.

ABSTRACT.

Mucho se ha discutido sobre la existencia de la gran falla del Guadalquivir que atraviesa la parte meridional de España desde el N.E. al S.O. Para contribuir al esclarecimiento de este problema, hemos estudiado detenidamente todos los datos sísmicos y gravimétricos obtenidos en España.

Por médio de los primeros, se ha fijado la posición de los epicentros de mas de 300 sismos ocurridos en el sur de España, encontrando que conforme á las leyes establecidas por Sieberg, están alineados segun las trazas de las dislocaciones. Tambien se ha comprobado que la línea del Guadalquivir limita la región donde se encuentran todos ellos. Al norte des esta línea, el suelo no se mueve y al Sur, por el contrario, se registran movimientos disunicos, casi todos los dias, lo que nos demuestra la existencia de una solución de continuidad, en los bloques corticales, que constituyen aquella zona.

Por médio de los valores de g, de la red gravimétrica española, corregidos por elevación, topografía y compensación isostática, esta última efectuada por Mr. BOWIE, en los EE.UU. de América, se han trazado las líneas isanómalas. La línea cero, dèlimita la depresión bética; su rama norte coincide próximamente con la línea del Guadalquivir y en su interior las anomalias son negativas, lo que nos prueba un hundimiento del bloque situado al sur y un relleno posterior de sedimentos mas modernos.

Finalmente, en los sondeos efectuados en Villanueva de las Minas, en las cercanías de la supuesta falla, ha habido uno que á los 900 m. de profundidad no habia cortado el terreno cambriano, mientras que otro situado unos cientos de metros mas al norte, le cortó á los 150 m.

Todas estas razones nos prueban la existencia de la falla, que deseamos comprobar por mediciones geofísicas de detalle.

60. GRAVIMETRIC AND SEISMIC EXPEDITION TO CENTRAL ASIA

BY

D. J. MUSHKETOV and P. M. NIKIFOROFF.

In autumn 1928, the Institute for Applied Geophysics and the Seismological Institute, Academy of Sciences of the USSR, undertook a gravimetric and seismic expedition to the Ferghana depression (Central Asia) and the mountain ranges bordering it from north and south, the observations having also been extended over the steppes north of the Alexandrovski range. Ferghana, a province of most intensive seismic activity, is at the same time characteristic for quite exceptional, as to numeric values, negative anomalies of intensity of the force of gravity (up to 0.358 cm sec²) as well as for considerable anomalies of its direction, i.e. for deflections of lead-wire reaching 42". That region is also known for grandiose tectonic phenomena which resulted in strongly developed folds, faults, thrusts and overthrusts. All the above features are closely related to each other and their extensive study is of exceptional scientific and practical value. The idea of such an expedition was put forward by the writers at the International Geological Congress in Madrid where it met with unanimous approval as the first attempt to apply physical methods to the solution of great geological problems referring to tectonics of deep layers of the earth crust, to genesis of mineral resources, to general conditions of equilibrium in the earth crust and the tendency of masses to displacement.

The Expedition which was carried out under the general direction of Prof. P. M. NIKIFOROFF assisted by Eng. S. K. CHIRIN, consisted of three parties respectively in charge of pendulums, gravity variometers and seismographs.

The pendulum party, under A. A. Popov, was entrusted with determination of relative values of the force of gravity and of deflections of lead-wire. Two cross-sections were executed, one near the estuary of the Ferghana depression, across the northern mountain branches Tashkent-Khodjent (five stations), and the other through the central part of the depression, Ferghana-Namangan-Aulie-Ata (eleven stations). Observations were carried out consecutively at following points: 1) Chamber of Weights and Measures, Leningrad; 2) Astronomical Observatory, Pulkovo; 3) Astronomical Observatory, Tashkent; 4) Kereuchi; 5) Chal-ata; 6) Kaliachi; 7) Khodjent; 8) Shakhimardan; 9) Ferghana City; 10) Yaz-awan; 11) Minbulak; 12) Mamay; 13) Iskavat; 14) Namangan; 15) Andijan; 16) Aulie-Ata; 17) village N. Ivanovskoie; 18) vill. N. Alexandravskoie; 19) Astronomical Observatory, Tashkent; 20) Chambers of Weights and Measures, Leningrad; 21) Astronomical Observatory, Pulkovo; a total of 21 relative determinations of the force of gravity (including repeated determinations in Tashkent and Lenigrad). Astronomical determinations of latitude and longitude were performed by means of observations of pairs after Zinger and Pevtzoff with Bamberg Universal Instrument, at the following points: 1) Tashkent; 2) Kereuchi; 3) Chal-Ata; 4) Kaliachi; 5) Khodjent; 6) Shakhimardan; 7) Ferghana; 8) Yaz-awan; 9) Minbulak; 10) Mamay; and 11) Namangan. At all these points observations were performed of magnetic elements of the magnetic field (vertical and horizontal components, deflection) by means of deflection magnetometer No. 9, type J. Bakhurin. In addition to railway journey, 500 km. were covered by road.

The gravity variometer party, with N. V. Veshniakov, at the head, was determining by the method of torsion balance the gradients of the force of gravity in the space between two points which showed particularly strong divergencies of intensity of the force of gravity. Such observations were undertaken in order to establish whether the above intensity varies gradually, or a sudden bound of the gravity value occurs, and in such case where namely. The values of the force of gravity being dependent upon the distribution of masses within the earth crust, very accurate detailed measurements of the field of gravitation by means of the above method, also appliable to prospecting, must furnish sufficient evidence for conclusions as to the underground relief of base rocks underlying the valley. For extreme points of observations of that kind were chosen Khodjent and Kaliachi, where determinations of the force of gravity as well as astronomical observations were carried out with particular accuracy. Between these points, 15 km. distant from each other, two parallel rows of 100 points each, of gravimetric observations were performed, the rows running at 250 m. distance. The extremities of the rows were connected by accurate levelling,

and around each of the 200 points a radial levelling was executed in order to estimate the terrain effects. The gravimetric observations of the party in question were carried out by means of two gravity variometers of the 1928 type (Seismological Institute—Institute for Applied Geophysics) constructed in the workshops of the Seismological Institute.

The Seismic party, under N. V. RAYKO, pursued following aims: 1) to establish the relief of deep layers of the earth crust, underlying the alluvions of the Ferghana valley (by methods of seismic prospecting), and 2) to determine the rate of propagation of elastic movements within those layers in order to establish the law according to which their values change in the lapse of time between two consecutive earthquakes. According to KOVESLIGETHY, the solution of that problem may furnish scientific ground for prevision of earthquakes. The works of the party were concentrated on the meridional section of the Ferghana depression along the line Ferghana-Namangan. After preliminary trials of the apparatuses and some experimental field work in the vicinity of Leningrad, the party left on 9 X for Ferghana City which was to be the starting point of its works. The party was equipped with two horizontal seismographs Wiechert-Mintrop, magnification 9,000 and 21,000 respectively, and a vertical one, type NIKIFOROFF (magnification 10,000), for photographic registration. Seconds were marked on seismograms from one and the same chronometer, more accurate estimation of time being secured by means of Geisler tubes fed by one and the same inductor. The moment of explosion was marked on seismograms by means of electromagnets of which the circuit was interrupted (breakage of conducts). Four so-called "Stations" were studied: 1) 3 km. south of Ferghana City; 2) 2 km. south of settlement Karasakal; 3) 1.5 km. south of settlement Minbulak, and 4) 2 km. north of Namangan. The former three are situated on quite even terrain, the latter in fore-mounts. During the work of the party 79 explosions were carried out and 236 seismograms recorded. The abundant evidence furnished by the Expedition is now being studied.

As preliminary communication we are giving here but the results of study of pendulum observations which show very interesting theoretical consequences. In the table annexed, the columns (8) and (9) contain theoretical values of gravity at the named in (1) stations as computed from HELMERT'S formula corrected for elevation (γ) and for topography and compensation (γ_1) according to HAYFORD'S formulae. In (10) are given the observed values of g, thence in (11) and (12) we have the free air ($\Delta g = g - \gamma$) and HAYFORD'S ($\Delta g_1 = g - \gamma_1$) anomalies respectively.

1	2		3		4	5	6	7	8	9	10	11	12
Number and Name of Station.	φ		λ		H	$\gamma_\circ$	Correction for Elevation.	Correction for topography and compensation.	Computed Gravity at Station.		Observed Gravity. at station.	Free Air anomaly.	Hayford anomaly.
							$\Delta\gamma$	$\Delta\gamma_i$	$\gamma=\gamma_\circ+\Delta\gamma$	$\gamma_i=\gamma+\Delta\gamma_i$	g	$g-\gamma$	$g-\gamma_i$
	°	′	°	′	meters	cm. sec. $^{-2}$							
1. Pulkovo.......	59	46,3	30	19,7	76	981,896	— 0·022	—	981,874	—	981,897	+ 0·025	—
2. Leningrad.....	59	55,1	30	19,1	4	981,908	— ·001	—	981,907	—	981,936	+ ·029	—
3. Tashkent.......	41	19,5	69	17,7	479	980,284	— ·148	— 0·036	980,136	980,100	980,081	— ·055	— 0·019
4. Kereuchi.......	40	53,7	69	29,3	442	980,245	— ·136	— ·045	980,109	980,064	980,046	— ·063	— ·018
5. Chul-Ata.......	40	39	68	28,2	748	980,225	— ·231	+ ·010	979,994	980,004	979,963	— ·031	— ·041
6. Khodjent......	40	14,7	39	20,1	400	980,188	— ·123	— ·073	980,065	979,992	979,932	— ·133	— ·060
7. Kaliachi........	40	8,2	69	40,7	535	980,178	— ·165	— ·072	980,013	979,941	979,898	— ·115	— ·043
8. Shakhimardan.	39	59,5	71	48,7	1,332	980,165	— ·411	— ·145	979,754	979,609	979,633	— ·121	+ ·024
9. Ferghana.......	40	23,0	71	46,9	573	980,201	— ·177	— ·086	980,024	979,938	979,862	— ·162	— ·076
10. Yaz-Awan......	40	39,7	71	44,1	412	980,225	— ·127	— ·085	980,098	980,013	979,903	— ·195	— ·110
11. Min-Bulak.....	40	52,0	71	39,7	390	980,244	— ·120	— ·085	980,124	980,039	979,927	— ·197	— ·112
12. Mamay..........	41	26,4	71	41,1	1,204	980,295	— ·372	— ·018	979,923	979,905	979,861	— ·062	— ·044
13. Iskavat.........	41	17,5	71	40,8	916	980,281	— ·286	— ·048	979,995	979,947	979,884	— ·111	— ·063
14. Namangan......	40	59,9	71	38,7	419	980,255	— ·129	— ·084	980,126	980,042	979,942	— ·184	— ·100
15. Andijan........	40	45,3	72	21,6	521	980,234	— ·161	— ·089	980,073	979,984	979,897	— ·176	— ·087
16. Aulie-Ata.......	42	54,0	71	22,4	620	980,426	— ·191	—	980,235	—	980,201	— ·034	—
17. N. Ivanovskoie	43	8,0	71	25,2	559	980,447	— ·172	—	980,275	—	980,267	— ·008	—
18. N. Alexandrov-skoie	42	38,5	71	35,2	879	980,402	— ·272	—	980,130	—	980,087	— 043	—

The annexed table represents the meridional section through the central part of the Ferghana depression, across Ferghana City and Namangan, as compared with the distribution of gravity anomalies Δg and Δg_1.

Both anomalies Δg and Δg_1 have a very easy and consequent course reaching the maximum of absolute value in the centre of the valley, the extreme values being very high namely $\Delta g = -0.107$ and $\Delta g_1 = -0.112$ cm/sec². Both anomalies are negative on the whole stretch, save for Δg_1 at Shakhimarden. In the North, at the entrance into flat steppes, g is approaching the normal value.

Thus, in the area of the Ferghana depression, a lack of compensation is established quite positively, which involves the tendency of that portion of the earth crust to vertical displacement upward, the latter circumstance being the cause of numerous strong earthquakes. As to the origin of the Ferghana depression, we are led to conclude that it was formed as the result of a squeezing of the earth crust, the sial-masses being pressed into a denser layer underlying the crust.

70. ANTEIL DES DR. EMIL HOLUB AN DER GEOLOGISCH-PALÄONTOLOGISCHEN ERFORSCHUNG SÜDAFRIKAS

VON

J. V. ZELÍZKO,
in Prag.

Der verdienstvolle Afrikaforscher Dr. EMIL HOLUB, welcher im Jahre 1902 in Wien im Alter von kaum fünfundfünfzig Jahren starb, gehörte entschieden zu den idealen Forschern vom polyhistorischen Schlage Humboldts, was aus seinen zahlreichen Publikationen über die wissenschaftlichen Resultate der beiden, in den Jahren 1872 bis 1879 und 1883 bis 1887 unternommenen Reisen, vor allem aber aus seinen grossen Reisewerken *"Sieben Jahre in Südafrika"* (1881) und *"Von der Capstadt ins Land der Maschukulumbe"* (1890), am besten ersichtlich ist, abgesehen von den prachtvollen, heute leider in der ganzen Welt verstreuten naturwissenschaftlichen und ethnographischen Sammlungen.

Alle diese Forscher der alten Schule, welche meistens auf eigene Mittel oder andere bescheidene Unterstützungen von öffentlicher Seite angewiesen waren, konnten selten Mitarbeiter verschiedener Spezielfächer auf ihre Reisen mitnehmen, so dass die ganze allseitige wissenschaftliche Tätigkeit auf den Schultern jedes einzelnen Forschers lag, was uns umsomehr mit Bewunderung und Achtung erfüllen muss.

Durch die von seinem Vater, einem tschechischen Provinzarzte geerbte grosse Liebe zur Natur angeregt, befasste sich Holub bereits in frühester Jugend mit ernsten Studien der Naturwissenschaften; er sammelte Käfer, Schmetterlinge, Pflanzen, Mineralien und Fossilien in der Umgebung seiner engeren Heimat.

Als zukünftiger Afrikaforscher, dem die grossen Taten und Entdeckungen des berühmten Livingstone ein leuchtendes Vorbild bedeuteten, wählte Holub die Medizin als geeignetstes Existenzmittel zur Verwirklichung seiner grosszügigen Pläne.

Nach vollendetem Studium, im fünfundzwanzigsten Lebensjahre, kam Holub sozusagen ohne Geld, aber voll Zuversicht und Hoffnung im Jahre 1872 von Prag nach Kapstadt.

Später bei den Diamantenfeldern im Inneren Südafrikas ankommend und auf eigene Kraft sowie bescheidene Mittel, welche ihm anfangs die dortige ärztliche Praxis darbot, angewiesen, konnte er sich doch bald die nötigsten mangelnden naturwissenschaftlichen Disziplinen aneignen, damit seine beabsichtigten weiteren Reisen der Wissenschaft den erwünschten Nutzen bringen sollten.

Damals vor fünfzig Jahren, wo selbstredend die geologischen Verhältnisse Südafrikas noch sehr mangelhaft bekannt und lückenhaft waren, stützten sich die Studien Holubs an die Resultate der ersten Pioniere der geologisch-paläontologischen Durchforschungen des genannten Gebietes.

Eine willkommene Quelle dazu lieferten ihm auch die in "*The Transactions of the South African Philosophical Society*" in Cape Town veröffentlichten diversen Studien und Aufsätze.

Wie mir bekannt ist, schätzte Holub stets die Forschungen der englischen und deutschen Geologen um Südafrika, zu welchen besonders E. J. Dunn, G. W. Stow, A. Schenk, E. Cohen, M. Schlichter, A. Hübner und andere gehörten. Mit dem noch lebenden E. J. Dunn, ehemaligen Direktor der Geological Survey of Victoria Australia, welcher zu Zeiten Holubs sich in Südafrika mit den geologischen Studien befasste, war Holub in langjähriger freundschaftlicher Verbindung.

Zur selben Zeit hat sich auch sein tschechischer Landsmann Geologe *O. Feistmantel* (—1848—1891), Autor des wichtigen Werkes "*The fossil flora of the Gondwana system*," um die geologisch-paläontologische Durchforschung Südafrikas verdient gemacht, wie aus dem von mir teilweise ergänzten Verzeichnisse seiner Publikationen in A. L. Hall "*A Bibliography of South African Geology to the end of* 1920." (Geological Survey, Memoir Nr. 18, P. 117, Pretoria 1922), hervorgeht.

In diesem Buche sind auch sämtliche diesbezüglichen Publikationen Holubs nach meinen Angaben auf Seite 177-178 angerührt.

Est ist selbstverständlich, dass während seines ersten siebenjährigen Aufenthaltes im Zentrum der klassischen, damals im Anfang des Betriebes stehenden Diamanten- und Goldfelder Südafrikas, Holub diese Fundstätten besonders interessierten und er trachtete die geologischen Verhältnisse derselben eingehend kennen zu lernen. Deshalb ist es kein Wunder, dass in seinen Schriften diese Vorkommnisse öfters erörtert werden.

Holub hielt ursprünglich sämtliche Diamantengruben für Öffnungen von Schlammkratern, glaubte aber nicht, dass diese Diggings von einem gemeinschaftlichen Kraterkanale abzweigen. Nur die in Old de Beers und Kimberley zutage geförderten Gesteine zeigten gewisse Ähnlichkeit und gaben der Vermutung Raum, dass diese beiden Diggings unterirdisch kommunizierende Kraterbecken sind. Was die River-Diggings anbetrifft, vermutete Holub, dass irgendwo in der Nähe des Flussbettes oder vielleicht an

seinem Rande, doch oberhalb Bloemhof, sich eine oder mehrere Kratermündungen befinden.

Auf der zweiten Reise änderte und vervollständigte Holub teilweise diese Ansichten auf Grund der damaligen neueren Forschung.

Von der ersten Reise Holubs stammt auch seine Publikation *"Die südafrikanischen Salzseen."* (Jahresbericht des Frankfurter Vereines für Geographie und Statistik, Frankfurt a M. 1881) und die gemeinsam mit M. NEUMAYR verfasste Abhandlung *"Ueber einige Fossilien aus der Uitenhage-Formation in Süd-Afrika"* (Denkschriften der Mathem.-naturwiss. Classe der kaiserl. Akademie der Wissenschaften in Wien, Bd. XLIV, 1881).

In der letztgenannten Publikation, deren geologischer Teil von Holub stammt, sind unter den von ihm beim Zondag- und Zwartkopfluss gesammelten Versteinerungen VON NEUMAYR auch zwei *neue* Arten: *Monodonta Hausmanni n.f.* und *Trigonia Tatei n.f.* bestimmt.

Diese Fauna der Uitenhageformation, deren geologisches Alter lang unklar war, hielten die beiden Forscher für neokome mit schwachem, jurassischen Gepräge, was auch in der *"Geologie Afrikas"* (Bd. II, Berlin 1928) von E. KRENKEL nach den Forschungen F. L. KITCHINS und R. B. NEWTONS neuerdings bestätigt wurde.

In der Monographie F. L. KITCHINS *"The Invertebrata Fauna and Palaeontological Relation of the Uitenhage Series"* (Annals of the South African Museum 7. Cape Town 1908), wurde aus der angeführten Formation auch *Trigonia Holubi* beschrieben.

Wie aus dem Inhalt des I-Bandes seines Reisewerkes ersichtlich ist, interessierten Holub auf der ersten Reise auch die morphologischen Verhältnisse sowie die Speleologie Transvaals.

Bei der kartographischen Aufnahme der Viktoriafälle hat Holub unter anderen auch die geologischen Verhältnisse der Umgebung dieses einzigen Naturphänomens berücksichtigt. Die Reproduktion dieser, dem II. Bande seines Werkes *"Sieben Jahre in Südafrika"* beigelegten Karte ist im Maßstabe 1:7000 m. ausgeführt. Die von Holubs Hand herrührende, im Besitze des Autors dieses Aufsatzes befindliche farbige Originalaufnahme der Viktoriafälle ist im Maßstabe 1 : 10,500 yards gezeichnet. Das Blatt ist 40 cm. lang und 32 cm. breit und der Besitzer desselben beabsichtigt ein Faksimile mit einigen Bemerkungen zu publizieren.

Nach seiner Rückkehr von der ersten Reise trachtete Holub während des vierjährigen, der wissenschaftlichen Tätigkeit und den Vorbereitungen zur zweiten Expedition gewidmeten Aufenthaltes in Wien, stets seine geologische Vorbildung nach Möglichkeit zu ergänzen und diese Fortschritte sind überall bei seiner nächsten, vier Jahre dauernden und, wie bekannt ist, so unglücklich beendeten Forschungsreise von Kapstadt in das Land der Maschukulumbe, bemerkbar.

Auf dieser Reise hat Holub zwar keine geologischen Aufnahmen gemacht, aber in seiner, dem II. Teile des Reisewerkes "*Von der Capstadt ins Land der Maschukulumbe*" beigelegten Routenkarte von Gazungula bis zu dem von ihm endeckten Franz-Josefs Gebirge im Jahre 1880, hat er überall die wichtigsten Formationen und Gesteinsvorkommen verzeichnet.

Natürlich müssen wir diese Ergebnisse von dem Standpunkte berücksichtigen, dass Holub doch kein Geologe vom Fach war und dass er sich vielseitig wissenschaftlich beschäftigen musste.

Den geologischen Verhaltnissen während der Reise gegen Norden widmete Holub bereits von Kapstadt eine besondere Aufmerksamkeit und überall sammelte er eifrig Gesteinsproben, Mineralien und Fossilien, welche er entweder früher nach der Heimat schickte, oder später mitnahm.

Die von Holub publizierten geologischen Resultate wurden auch später von S. Passarge in seinem "*Beitrag zur Kenntnis der Geologie von Britisch-Betschuana-Land*" (Zeitschrift der Gesellschaft für Erdkunde zu Berlin, Bd. XXXVI, 1901) günstig beurteilt.

Es ist nur zu bedauern, dass das Tagebuch Holubs mit den wichtigsten geologischen Aufzeichnungen durch den räuberischen Überfall der Maschukulumbe bei Galulonga verloren ging.

Das von Holub mitgebrachte Material wurde dann mit den anderen prachtvollen naturwissenschaftlichen und ethnographischen Attraktionen und Sammlungen seiner zweiten Reise zuerst im Jahre 1891 in Wien und ein Jahr später in Prag ausgestellt und dann an verschiedene Schulen im damaligen Oesterreich, sowie an heimatliche oder auswärtige wissenschaftliche Institute und Museen, wie alle übrigen Gegenstände, verschenkt.

Nach dem von J. Kafka verfassten "*Illustrierten Führer durch die südafrikanische Ausstellung des* Dr. E. Holub," in Prag 1892, brachte der Forscher aus Südafrika vor allem zahlreiche Proben von der diamantenführenden Erde und Tuffen mit den sie begleitenden Mineralen, wie Ilmenit, Zirkon, Magnesit, Granat, Vaalit u. a., ferner verschiedene Abarten des goldführenden Quarzes, Kupfererze und gediegenes Kupfer von Springbockfontein im Namaqualande, Eisenerze und Galenite von Port Elisabeth, Manganerze von Tulbach und viele andere Erze, Minerale und Gesteine (Gneise, Tonschiefer, Diabase, Diorite, Porphyre, Syenite, Granite, Melaphyre, etc.)

Die Paläontologie Südafrikas war durch schöne, aus der Steinkohlen-Trias- und Kreideformation stammenden Funde repräsentiert.

Neben den Originalen zu der gemeinsamen Publikation mit Neumayr über die Fossilien der Uitenhage Formation, fand man auch interessante Wirbeltierreste aus den Triasablagerungen des Distriktes von Colesberg namentlich Knochen der Dicynodonten von Kuilfontein und eines Schnauzenkrokodiles, gleichfalls aus der Gegend von Colesberg, sowie zahlreiche Trias- und Kreidepflanzen.

Zur eigenen Information, betreffs der geologischen Verhältnisse der südafrikanischen Gold- und Diamantenfelder, erhielt Holub von den Direktionen der verschiedenen Gewerkschaften manche Pläne, Diagramme, Schichtenprofile und Photographien der wichtigsten Aufschlüsse, welche der Forscher in seinem Wiener Arbeitszimmer stets vor Augen hatte.

Über die südafrikanischen Gold- und Diamanten-Lagerstätten, mit Berücksichtigung ihrer weltwirtschaftlichen Bedeutung, hat Holub in Europa mehrere Vorträge gehalten und über dasselbe Thema auch folgende informative Publikationen veröffentlicht:

Geological Exploit of the Gold Deposit Formations and their Geographical Location. (Illustrated Christian World, New-York, October 1896, Nr. 94, pag. 7).

A Brief History of the Discovery, and an Account of the Working of Diamond Mines (Ibid, August 1896, Nr. 92, p. 7).

Location of the Diamond Fields and their Geological Formation (Ibid., September 1896, Nr. 93, p. 7).

Zu seiner im "Sborník" der böhmischen geographischen Gesellschaft in Prag 1889 erschienenen Abhandlung "*Z Afriky*" (mit dem ins Deutsche übersetzten Untertitel: "Beitrag zur Rundschau über den neuesten Stand des schwarzen Erdteiles"), schilderte Holub ausführlicher die Verhältnisse der Goldlagerstätten von Transvaal und Rhodesia auf Grund der damaligen neuesten geologischen Forschungen.

Vom allgemeinen geologischen Interesse, was Südafrika anbelangt, sind noch folgende Arbeiten Holubs zu erwähnen:

Interesting Formations of the Cape Period, Extending through the Colony and the Transvaal Republic (Illustrated Christian World, New York, November, 1896, Nr. 95, p. 3).

How Caves and Underground Rivers Came to Exist—Wonders of the Subterranean Passages-Quartz Veins and Gold Rifts (Ibid., December 1896, Nr. 96, p. 15).

The Age, Geographical Location, and Geological Formation of the Karroo Period—Valuable Mineral Deposits, (Ibid., January 1897, Nr. 97, p. 13).

Es ist selbstverständlich, dass auch die klassischen und reichhaltigen Wirbeltierfunde aus der südafrikanischen Beaufort-Serie des Karru-Systems Holub ungemein interessierten.

Dem Studium der merkwürdigen Saurier der angeführten Formation widmete sich Holub besonders eifrig nach seiner Rückkehr von Amerika, wo er auf Einladung der Geographical Society in Washington, in den grös-

seren Städten Amerikas seit Ende des Jahres 1894 bis Anfang des Jahres 1895 Vorträge hielt, und dabei auch die Bekanntschaft mit dem berühmten Paläontologen C. O. Marsh machte und von ihm seine zahlreichen Publikationen über die fossilen Wirbeltiere heimbrachte.

Über die südafrikanischen Funde hat Holub, wie mir bekannt ist, folgende Publikationen veröffentlicht:

Some Interesting Fossils of Reptiles, Birds and Beasts, and the Strata in which They Have Lain for Centuries—The Beaufort Formation (Illustrated Christian World, New York, March 1897, Nr. 99, p. 9).

Discoveries of Reptile Fossils, and Their Part in Establishing a Relationship with the Mammals (Ibid., May 1897, p. 5).

Some Striking Illustrations of the Similarity Between Mammalia and Reptilia (Ibid., June 1897, p. 3).

Von grosser Wichtigkeit für Vergleichsstudien der Höhlenwandmalereien und Zeichnungen des paläolithischen Menschen in Frankreich und Spanien sind die von Holub auf beiden Reisen gesammelten zahlreichen prachtvollen Felsgravierungen der Buschmänner, welchen jetzt einige Forscher ein sehr hohes Alter zuschreiben.

Diese, in verschiedenen europäischen Museen verstreuten Funde, von welchen die zahlreichsten und schönsten sich im Naturhistorischen Museum in Wien befinden, publizierte der Verfasser dieses Aufsatzes in der Monographie "Felsgravierungen der südafrikanischen Buschmänner" (Auf Grund der von Dr. Emil Holub mitgebrachten Originale und Kopien) in Leipzig 1925.

Vor der projektierten dritten Expedition, welche diesmal von Kapstadt quer des afrikanischen Kontinentes bis nach Kairo führen sollte, versprach sich Holub besonders von der geologischen Forschung während dieser Reise grosse Erfolge und war immer mit diesbezüglichen Vorstudien beschäftigt.

Leider aber hat der frühzeitige Tod des Forschers diesen gewagten Plänen ein Ende gemacht.

Jedenfalls hat sich Holub nach seinen besten Kräften auch um die geologisch-paläontologische Erforschung Südafrikas bemüht und sein Name wird in den Reihen der wackeren Bahnbrecher der Afrikaforschung immer einen ehrlichen Platz einnehmen.

71. SOLAR REGISTRATION BY PRE-QUATERNARY VARVE-SHALES

BY

GERARD DE GEER.

In 1910, at the opening of the International Geological Congress in Stockholm, I had the privilege of presenting a summary of my results since 1878 from endeavouring to work out an exact so-called *Geochronology*. Later on I have tried to show that the late-Quaternary Swedish Time-scale is applicable to evidently all of the late-Quaternary glaciations on both of the hemispheres.

This time-scale was put together by a continuous actual counting of the whole succession of annual varves among the laminated sediments from the end of the last Ice Age.

The remarkable, world-wide coincidence as to the thickness-variation of these varves seems scarcely explicable in any other way than by annual variations in the amount of solar melting-heat, reaching every year the different ice-sheets of the last glacial epoch. This grand, natural self-registration of solar radiation is at present fixed and noted down for 16.500 years backwards from our century.

Now it seems justified to make a first attempt at investigating in the same way the pelitic melting-sediments or *varved shales* from the glaciations of earlier geological periods in order, if possible, to elucidate the laws of solar radiation during more distant ages as compared with those already within our reach. Hereby it seems appropriate to commence with the greatest and best known of the pre-Quarternary glaciations, or that which from paleontological evidence is generally referred to the Permian or the Permo-Carbonic period.

Judging from the geochronological teleconnections at present performed, it seems already to be ascertained that the Quaternary glaciations in different tracts of the earth were synchronous, and it may be fair to make the same assumption with regard to at least more widespread glaciations from pre-Quaternary periods.

It seems thus rather probable that the main Permo-Carbonic glaciations may be synchronous as depending on a common cause, or the variations in the supply of heat from the sun to the earth.

If this be the case, it may not be impossible, by means of assiduous searching, to hunt up sufficiently long series of undisturbed varve-shales representing the annual melting-sediments from pertaining glaciations in different parts of the earth.

Ever since ROBERT SAYLES appliėd the author's Quaternary varve explanation to the Permian glacigene formation in the Boston region and described in such an excellent way its beautiful varve-shales, corresponding annual varves have been reported from several other of the Permian glaciations.

Especially suggestive in this respect is the book of A. P. COLEMAN on Ice Ages, recent and ancient, as he had made, in 1910, some personal acquaintance with the varve studies in Sweden and was well aware of their extension to North America.

From his personal visit to several of the different glaciated regions from the Permian period he explicitly reports annually laminated or varved sediments closely connected with the Permian moraines or tillites.

Still, it seems that hitherto no one has tried to make any measurements of such ancient varves, and therefore the purpose of this note is to propose an international co-operation in order to bring about in different parts of the earth measurements of this kind as comprehensive and accurate as possible.

During the present Swedish Hedin-expedition to Central Asia its head geologist, DR. E. NORIN, has discovered a very interesting Permo-Carbonic glacial formation, about 700 m. thick, with tillites, glacifluvial gravel, and varve-shales, these latter being no less than 150 m. thick. During his recent visit in Stockholm he declared himself very willing to measure and to photograph as long varve-series as possible and also, by help of his assistant geologist, DR. N. G. HÖRNER, to extend these investigations as far as the conditions would permit. In this way we can possibly obtain from Central Asia a rather long Permian time standard, thus increasing the possibility of finding out some corresponding parts of synchronic varve-series from other regions.

As another of my varve-expert co-operators, DR. C. CALDENIUS, who has been engaged in the Geological Survey of Argentina during the last four years, mainly for geochronologic investigations with regard to the Quaternary glaciations of Patagonia, is now, on my proposal, planning a similar expedition to New Zealand and, if possible, also to the Permo-Carbonic glacigene varve-shales of south-eastern Australia.

Furthermore, it is to be hoped — with respect to the investigations here proposed — that several new co-operators may be found among the

great number of geologists who now, at the International Congress in Pretoria, will have an opportunity of making a nearer acquaintance in the field with the highly interesting Dwyka-glaciation of South Africa. It seems, indeed, to be the right moment for starting the enterprise in question.

It may be that the difficulties by the proposed measuring of shale-varves often will prove to be considerably greater than in the case of clay-varves, but if careful and methodical measurements be carried out and duly controlled, they will no doubt soon enough give very interesting indications concerning the variation of the sun-radiation during this remote period. Furthermore, if we should succeed getting teleconnection between glaciations in different regions of the earth it might be possible to get valuable corrections of the corresponding solar curve. At the same time it would be stated whether the varve-deposits and the glaciations in question were exactly synchronous. This would also afford the first reliable starting-point for considerations as to the real synchronism of the biogeography and the biomigrations of the epoch in question.

On the whole it seems indeed worth while to make some earnest efforts to attain, not only an exact correlation of such very ancient deposits, but also perhaps to reach the rather fascinating result of unravelling a series of annual variations in the radiation from the sun during an epoch which, according to the radium desintegration, has been estimated, may be very roughly, to lie some 200 millions of years before our time.

In order to promote such an international investigation for the purpose named it may be appropriate to transmit publications, photographs, specimens, and other informations to the present author under the address: The Geochronological Institute of the University, Sveavägen 34, Stockholm, Sweden.

Appendix.

A.—Method of measuring pre-Quaternary Shale-varves.

When measuring Quaternary clay-varves it is generally possible to bring about a plane section preferably at right angles to the varves. With respect to hardened varve-shales, this advantage is not at hand. Where varve-shales are cut and exposed along plane fissures, the measurements can be carried out as in the ordinary way by marking the winter-limits between the varves with a sharpened lead-pencil on strips of paper. At the basis of every strip is written the word: down, and at the upper end the word: up. At the back side of the strip is written the exact locality, the greatest place in the neighbourhood, the date, and the full name of the observer. At the jointing-point of two successive measuring-strips an identical cross or other sign together with an identical letter is marked on both, so as to prevent every possible mistake.

If the limit between some varves is indistinct, this must be marked by a sign of interrogation, and if the normal varve-series is broken by slipped or otherwise disturbed varves, such lacunae must be explicitly marked on the strips. Thereby it is of course important, if possible, to overbridge such local lacunae by parallel measurements of corresponding normal varves in the neighbourhood.

The angle, formed by the plane measuring-surface with the varves, is to be noted

When the measurement is to be continued at a new section, it is important with certainty to ascertain that some common varves are measured at both places.

Where the measurements cannot be carried out on plane surfaces, the thickness of the varves is to be determined by a measuring-tape, and the figures for every varve to be written down without any lacunae or iterations.

Being always very useful, it seems almost necessary, when measuring shale-varves, to make at every locality some parallel measurements for the sake of control and correction in order to get as reliable variation-series as possible. For the same purpose it is very useful to get from different localities in each region such controlled measurements. If it thereby should turn out that some varves were common to different regions, it would be possible to combine the measurements to somewhat longer series thus increasing the possibility of teleconnection At the same time the thinning out of an identical varve from one neighbouring locality to another would indicate in which direction the sediment was spread out and from where it was coming.

Where the annual cycle of the varves is photographically distinct, it is of great value to collect continuous series of photographs, provided with a metric scale and taken as accurately as possible at right angles to the vertical section of the varves.

It is easy to mark out with a lead pencil the varve limits of a good negative, projected on a big paper, put up on the screen. Afterwards, straight lines are drawn at right angles to such parts of the varves marked, the limits of which are parallel, and such partial measurements are combined to a continuous series.

B. Some indications concerning Permian varve localities.

Asia.

E. Norin: In Kuruk Tagh Mountains; 41° N. Lat. Thickness about 150 m., probably indicating thousands of years.

Africa.

A. P. Coleman: Not far from Laingsburg, at Witteberg River valley about 250 km. ENE. of Cape Town; 33°.30' S. Lat. At the top: typical tillite, below: well stratified varve-shales, not disturbed, with scattered drifted boulders, at the bottom shales without boulders. The glacier had moved southwards without ploughing up the varve-clays.

Alex. L. du Toit: Widespread uniformly stratified shales of the southern Dwyka in South Africa probably indicate great marginal lakes before as well as after the main advance of the ice.

Nearly two miles east of Nordweni, in Natal, the basal tillite is abruptly followed by fully 40 feet of buff-coloured laminated shales, sometimes rather gritty, containing here and there erratics up to two feet in diameter; these are followed by unbedded tillite, and that in turn by the glacifluvial sandstone. Some six miles WSW. of Nordweni are mentioned four to six feet of beautiful varveshales rucked up in a sharp little arch, presumably by ice pressure; varves are split up into slabs from a quarter to half an inch in thickness and are quite corresponding to the annual banded glacial clays in Sweden. This is the only locality of this type which du Toit had seen in South Africa. The deposition of the varve-shale is assumed here to have taken 150-200 years.

W. Kaudern, Swedish geologist, thinks possibly to have observed a varve-shale section at the harbour of East London, about 33° S. Lat.

Australia.

C. A. Süssmilch and T. W. E. David: describe some permo-carbonic varve localities about 140 km. NNE. of Sydney, 30 km. N. of Newcastle, about 32°, 20' S. Lat. Varve shales having the coarse layers yellow to brown and coarse enough for its particles to be visible to the unaided eye, the fine layers are gray to white in colour and utterly fine grained. The coarser layers frequently exhibit minute false bedding and merge upwards into the finer layers, but the junction between a fine layer with the next coarse layer above is usually quite sharp. The thickness averages often about two-thirds of an inch, so that the 200 feet of these varve-shales which occur at Seaham must have taken about 3,000 years to deposit. Layers from four to six inches thick and consisting of fine material only occur, but are few in number; similarly some thicker layers of course material only also occur. Occasional isolated pebbles and also regular pockets of such pebbles are found. At Seaham and Paterson two varve series occur together about 200 feet thick. The varve horizon can be traced a distance of over 20 miles from Raymond Terrace road to Gresford. These glacial deposits have earlier been referred to the Permo-Carbonic and later on to the Kuttung series.

North America.

R. SAYLES: Squantum Head at Boston, very beautiful varves and tillites, which the author had the opportunity of visiting in 1920 under the guidance of MR. SAYLES and PROF. WOODWORTH.

South America.

T. G. HALLE: Falkland Islands, sandy varve-shales a few m. thick in connection with tillite.

Several other occurrences are mentioned as somewhat more questionable.

72. ACTIVITY OF THE REORGANIZED RUSSIAN GEOLOGICAL COMMITTEE (GEOLOGICAL SURVEY).

BY

P. KOVALOFF.

The original intention was that the paper dealing with the subject of this article should have been presented to the XV International Geological Congress during its session in Pretoria in July-August, 1929, by the Russian Representative, PROF. D. MUSHKETOV, but the latter was prevented from doing so on account of the unexpected delay in the arrival of the necessary materials, which were only received in Pretoria after his departure. He has therefore requested the writer to make good this omission by making use of the materials mentioned. The present paper is prepared in compliance with that request.

Since the origin of the Russian Geological Committee in 1882 and up to the year 1918—when the writer of this paper got out of personal touch with that Institution — it was organised on the usual lines of Geological Surveys in other countries and was carrying out (on a comparatively modest scale, with a yearly budget of some £20,000—£30,000) its principal work — the systematic geological mapping of European Russia on a scale of 10 kilometers to the inch; conducting also special geological investigations in the most interesting (from a mining industrial view-point) districts in European Russia, as well as in Siberia and other outskirts of Russia, and, occasionally, in giving geological consultation, at the request of the government institutions and private persons.

From 1918 onwards the scope of the Russian Geological Committee's activity has increased to such an extent in comparison with the work outlined above, that it would be no exaggeration to say that at the present moment this Institution occupies in this respect an unique position amongst similar Institutions of other parts of the world.

As previously mentioned, the yearly budget of the Russian Geological Committee, up to the year 1918 did not exceed some £30,000, and its work was carried on in the field by some 40-50 geological parties, in which 40-60 geologists and associated geologists were engaged.

In the year 1925/26, that is only 8 years later, the budget of the Committee had increased to £438,000, in the year 1926/27 to £720,000, in the year 1927/28 to £1,050,000, and in the year 1928/29 to £1,350,000. According to the financial plan of the Russian Government for the period of the next five years, the budget of the Geological Survey for the year 1923/33 will represent the colossal figure of £5,918,000.

The increase in the number of parties engaged in field work conducted by the Committee in different parts of U.S.S.R., will be seen from the following table:—

1925/28	300
1926/27	389
1927/28	628
1928/29	678

At the end of a 5 year period, i.e. in the year 1932/33, it is intended to increase the number of parties, engaged in field work, to 1,800.

The permanent staff of qualified geologists in the Russian Geological Committee in the year 1928/29 reached 70, to which, during the period of field work, as many as 880 associated geologists were added on temporary engagements.

Towards the years 1932/33 it is intended to increase the permanent staff of qualified geologists to 166, in addition to which, during the period of field work, over 3,000 of mostly qualified geologists will be temporarily engaged.

In addition to this, in the course of prospecting, etc., work, conducted by the Committee, in 1928/29 as many as 1,400 persons of high and medium technical education were engaged which number towards the years 1932/33 it is intended to increase up to 4,630.

Such an unprecedented and rapid increase of the scope of activity of the Russian Geological Committee was given rise to by the unique position in which the geological service of U.S.S.R. found itself after the nationalization of all private industrial enterprises, when subsequently steps were taken by the Government for the restoration of the industry to the pre-war level, with the view of further systematic development, according to the 5-year programme in order to meet the needs of rapidly increasing internal consumption.

The question of the mineral resources of the country for the satisfaction of the needs of industrial enterprises in raw material has thus acquired as especial acuteness, and as all these enterprises, after the nationalization belong to the Government, and are conducted by the Industrial Trusts formed for each particular branch of the Industry and wholly controlled by the Government itself, the latter naturally made full use of the Russian Geological Committee as the only competent authority on all questions concerning the mineral resources of the country.

Thus it came about that the Russian Geological Committee became the chief and only Geological consultant for the whole mining Industry of the U.S.S.R. and, as such, took charge of all the prospecting work over the whole length and breadth of the country. Its activity almost suddenly has acquired a practical character and the chief object, with which it was originally instituted — geological mapping — receded, at least temporarily, into the background.

The whole prospecting work in Russia which was formerly conducted almost exclusively by private enterprises, sporadically and without a systematic plan, and often, under incompetent supervision, has now changed its character, giving place to systematic scientific prospecting according to a definite plan intended to meet the needs not of separate metallurgical concerns, but in raw materials of the industrial enterprises, agriculture building requirements, etc., of the country as a whole.

This policy has rapidly brought results. As most important the following may be mentioned:—

A discovery of extensive deposits of potassium salts along the Western slope of the Ural Mountains in Beresnikovsky and Solicamsky districts.

The discovery in the same district of a new oil region which promises to be very extensive and of vast commercial importance.

The discovery of three new deposits of copper ore in the Urals, and three in Kasakstan. The discovery of a number of new deposits of cassiterite in the Trans-Baykalien District of Eastern Siberia, etc.

In the deposits previously known the prospecting work, conducted by the Geological Committee has resulted in a considerable extension of the known ore reserves (ore in sight): of iron ores — in the Krivoi Rog District in Southern Russia; of coal — in the Urals and Caucasus; of copper and asbestos — in some districts of the Urals, etc.

As previously mentioned, since the Russian Geological Committee took charge of all prospecting work in the U.S.S.R. its activity in the accomplishment of its chief object — preparation of the Geological map of U.S.S.R. — has temporarily receded into the background. According to the programme of the next 5 years period this side of the activity of this Institution is again assigned its due place, while the practical character of this activity is still preserved in full, and even extended. The chief functions of the reorganized Geological Committee now are:—

1. The systematic and detailed study of the geological structure of territory of U.S.S.R. (geological survey) and the preparation of the geological map of the whole territory of the Union and its separate parts.
2. The search and the systematic geological and economical study of mineral resources and of the sources of underground and mineral

waters by means of scientific prospecting and development work (industrial prospecting) for the purpose of securing the raw material of mineral origin for the operating as well as for new mining and industrial enterprises and of the extension of their known reserves.

3. The calculation and recording of the reserves of mineral resources of U.S.S.R., of the sources of underground and mineral waters.
4. The scientific research work; the systematisation and publication of the results of the geological work of the Committee; popularisation of geological knowledge; the creation of museums, laboratories and other subsidiary scientific institutions of that kind.
5. The Geological consultation of Government Institutions and the Industrial enterprises of the U.S.S.R.

This extensive programme is accomplished by the Committee; 1.—Directly through the Central Institution in Leningrad. 2.— through the local branches of the Committee, acting according to the programme and instructions given by the latter.[1] and 3.—through Industrial Trusts conducting prospecting and development work in some places, under the general direction of the Committee, which is found, by technical considerations, preferable to the work being done directly by the Committee.

The programme of the Committee for the 5 years' period of 1929/33 was prepared in strict accordance with the plan of the industrial development of the U.S.S.R during this period, the chief object being to secure (by the extension of the knowledge of the reserves of the known mineral deposits and by the search for new ones) an uninterrupted supply of the necessary quantity of raw materials for this development during the current and well into the next 5 years period.

Referring now to the separate functions of the Committee enumerated above, the following is the programme for the next 5 years in respect of each of them:—

1. *The Geological survey work and the preparation of geological maps.*

In the years 1926/28 the geological mapping proceeded at the rate of about 150,000 square kilometers per year. During the period 1929-1933 it is intended to cover an area of over 845,000 square kilometers, the result of which work, in conjunction with the survey of previous years, will be the preparation of the maps:

(a) The mining districts of the Urals (on about 200 separate sheets) on the scale of 1 : 200,000.

1 There exists at present 10 such branches in Moscow, Sverdlovsk (formerly Ekaterinburg Urals), Novocherkassk (S. Russia), Tomsk (Western Siberia), Irkutsk (Central Siberia), Vladivostock (Eastern Siberia), Alma-Ata (Kazakstan), Kiev (Ukraine), Tashkent (Turkestan).

(b) Ukraine (more than 70 sheets) on the scale of 3 kilometers to the inch.
(c) The Central Russia, on a scale of 10 kilometers to the inch.
(d) The mining districts of Altai Region (Western Siberia) on a scale of 3 kilometers to the inch.
(e) The Eastern Trans-Baikalian Region, on a scale of 5 kilometers to the inch.
(f) The Russian Territory in Central Asia and Kasakstan on a scale of 40 kilometers to the inch.
(g) The Northern part of European Russia on a scale of 1 : 1,500,000 (intended to be part of the International Geological map of Europe).
(h) The whole territory of the U.S.S.R. on a scale of 1 : 500,000.

The choice of the regions, where the geological mapping has to be carried out, is made in strict accordance with the programme of the prospecting activity of the Committee (for which this mapping represents a necessary base), outlined below.

Beside this, separate geological expeditions in the remote parts of the U.S.S.R. (Kola Peninsula, the coast region of the White Sea, Bolshesemelskaya Tundra, Novaya Semla, Kamtchatka, Tchukotsky Peninsula, the coast region of the Ochotsky Sea, etc.), as well as the detailed study of the geology of the Caucasus by means of frequent traverses of the Caucasian Chain of Mountains, are included in the programme of this Section for the 5 years period referred to.

In close connection with the geological mapping is the work of the topographical survey, which serves as a base for the geological survey work and proceeds under the charge of the Committee. According to the programme, the number of topographical field parties will be increased during the 5 year period from 26 (1928/29) to 190 (1932/33) while the number of field parties for geological mapping will remain approximately stationery in the neighbourhood of 160.

2. *The study of mineral deposits and prospecting work.*

This side of the work of the Geological Committee, comprising 6 sections (Metallic, Gold and Platinum, Coal, Oil, Non-Metallic Minerals and Hydro-geological Sections), is very extensive and falls into the three divisions:

(1) The detailed study of the known deposits by means of detailed geological survey and prospecting (boring, surface prospecting);
(2) the prospecting work (mostly by boring or underground development work) in order to ascertain the ore reserves; and

(3) the geological traverses connected with surface prospecting, in the new regions in the search for new ore deposits and for potential mining Districts.

Part of the work, coming into the second of the sub-divisions mentioned, is accomplished, under the supervision of the Committee, by the Industrial Trusts. But in those districts where the existing deposits do not, as yet, represent the object of exploitation by Trusts or in such productive deposits, the geology of which is complicated and not yet sufficiently understood, the Committee takes direct charge also of this section of the work.

In conjunction with this side of the Committee's activity it must be mentioned that the preparation of the hydrogeological maps, especially for the regions of U.S.S.R. not possessing a sufficient surface drainage, and where the question of the water supply for domestic and industrial purposes and agriculture acquires especial acuteness. This work, as well as the study of the sources of mineral waters of the U.S.S.R. is in charge of a special (hydrogeological) Section of the Committee.

Apart from the usual methods of prospecting, the Committee since 1927 has employed geophysical methods of prospecting more and more extensively, (electrical, gravimetric, magnetometric and radiometric methods). Especially organised for this purpose, the Geophysical Section of the Committee has this kind of prospecting work under its immediate charge. Apart from the field work, which has already resulted in the discovery of new ore bodies (for instance of copper ore in the Urals, of a number of iron ore deposits in Southern Russia — especially in the vicinity of Kremenchug and elsewhere, and in the elucidation of some of the questions connected with the geology of the known deposits, e.g. of the platinum deposits in the Nijhie-Tagilsky district of the Urals), the geophysical Section conducts in its laboratories and Experimental Station research work on new methods. Up to now, this research work has resulted in the elaboration of two new methods of electrical, of one method of magnetometric prospecting, and of one radiometric method, the latter has already resulted in the discovery of monazite in the Enisey district of Western Siberia; of the minerals of Uranium, Thorium, Niobium and Tantalum, as well as of some new sources of radioactive water — in Transbaikalia (Eastern Siberia).

It is intended during the 5 years period to cover by these methods of prospecting an area of approximately 4,000 square kilometers in various parts of the U.S.S.R.

The most extended development of the prospecting activity of the Committee on the base metal ores during the 5 years period will take place in the Urals, Kasakstan and Ukraine, the chief work being concentrated on prospecting for copper ores, iron and manganese ores, and complex ores of lead, zinc and copper. A considerable amount of prospecting work, largely

by Industrial Trusts under the Committee's supervision, is intended to be carried out in the coal basins of the U.S.S.R. especially in the Donetz basin, in the oil regions and in the regions of the gold and platinum occurrences.

The number of geologo-prospecting parties engaged in this work will be gradually increased during the period of 1929/33, in the following manner:—

	1928/29	1932/33
Copper, lead, zinc, etc., ores	93	200
Iron and Manganese ores	29	70
Gold and Platinum	74	265
Coal	57	90
Oil	54	100
Non-metallic minerals	52	151
Building materials	32	123
Hydro-geological parties	55	299
	446	1,298

3. *The economic study of the mineral resources of U.S.S.R. and the record of ore reserves.*

This part of the Committee's activity is carried on by a special (Economic) Section, which is also engaged in the complication of Mining Statistics.

4. *The Scientific Research Work.*

This part of the geological Committee's work is accomplished by an extensive "Section of Subsidiary Scientific Institutions," comprising:—

(a) The Subsection of monographical Research, (Palaeontological, petrographical and Mineralogical) and Museum; (b) The Subsection of Chemical Research and (c) the Subsection of Subsidiary Institutions (Library, preparatory rooms, etc.), with suitably equipped chemical, petrographical, mineralogical, etc., laboratories, photographic pavilion etc.

The main objects of this section are:—

1. The study of the palaeontological petrographical and mineralogical collections of the Committee and the preparation of corresponding monographical works.

2. The palaeontological petrographical study and determination of the materials, obtained in the course of the field work of other Sections of the Committee.

3. Systematisation and supplementing of Museum collections.

For this latter purpose as well as for the field study of various geological questions for monographic works this section intends to organise field work by a number of special parties.

At present the following subjects are marked for the monographic works of the Section.

(1) Granite-gneissose formations of the U.S.S.R.
(2) Magmatic alkaline rocks of the U.S.S.R.
(3) The petrography of the oil bearing strata of the U.S.S.R.
(4) The crystalline schists of the U.S.S.R.
(5) The petrography of the quaternary deposits of the U.S.S.R.
(6) The basic effusive and hypabyssal rocks of the U.S.S.R.
(7) The regions of the recent and contemporary volcanism in the U.S.S.R.
(8) Acid and intermediate effusive rocks of the U.S.S.R.
(9) The petrographic study of the strategraphic sections.
(10) Ultra basic magmatic rocks.

The foregoing brief exposition shows the increase of the activity of the Russian Geological Survey for which the term "colossal" would be a most suitable expression. Whether the unprecedented programme of this Institution for the next 5 years will be fully realised depends mostly on the possibility of finding the necessary quantity of qualified workers for the Committee's field work. For this purpose especial measures are intended for the extension of corresponding faculties of the Universities and the High Technical Schools. At any rate, what was accomplished in the course of the recent years speaks in the favour of the success, and the most important practical results attained thus far represent the best answer to the view still expressed in some quarters that the work of the Geological Survey has only an academic value, and that the allocation of the sums for this purpose in the country's budget represent little more than a sort of luxury.

73. ÜBER DIE PHYSIKALISCHEN EIGENSCHAFTEN GEOLOGISCHER KÖRPER

VON

H. Reich.
Berlin.

Die Zeit grundsätzlicher Neuerungen auf dem Gebiet der angewandten Geophysik scheint zunächst vorüber zu sein. Es wird zwar überall an der Verbesserung der Apparaturen und Methoden gearbeitet, aber etwas, was revolutionierend auf die Entwickelung dieser Verfahren hätte wirken körnen, ist seit dem letzten Kongresse nicht mehr herausgekommen. Was jetzt am meisten interessiert, ist die Erforschung der Anwendungsmöglichkeiten der geophysikalischen Methoden. Dazu gehört u.a. in erster Linie eine systematisce Erforschung der physikalischen Eigenschaften grosser geologischer Körper. Es liegen hierüber zwar eine Menge von wertvollen Einzelbeobachtungen vor, aber eine systematische Zusammenfassung fehlt bisher, und ist auch noch kaum möglich. Jedenfalls ist es aber nicht zulässig, wie man das noch immer in der einschlägigen Literatur lesen muss, die an einzelnen Mineral-oder Gesteins-Stüken festgestellten physikalischen Eigenschaften auf eine ganze Lagerstätte oder einen sonstigen Gesteinskörper zu übertragen. Ein Kristallaggregat (Gestein) verhält sich eben physikalisch ganz anders als ein Einzelkristall, und ein Gesteinsaggregat (geologischer Körper) ebenso ganz anders als ein einzelnes aus dem natürlichen Zusammenhang gerissenes Gesteinsstück.

Ich will im Folgenden versuchen, für die 4 geophysikalisch wichtigsten Eigenschaften der Gesteine—nämlich die Dichte, die Elastizität, die Magnetisierbarkeit und die elektrische Leitfähigkeit die wichtigsten Gesichtspunkte zur Beurteilung dieser Eigenschaften bei natürlichen Gesteinsvorkommen zu umreissen.

Da ist zunächst die *Dichte* der Gesteine, die für die Anwendung gravimetrischer Methoden massgebend ist. Den Geophysiker interessiert nicht das spezifische Gewicht eines einzelnen Mineralkorns oder einer bestimmten Gesteins-substanz, das der Mineraloge oder Petrograph zu bestimmen sucht. Er will vielmehr das *natürliche Raumgewicht* eines bestimmten Gesteinsvorkommens wissen. Dies natürliche Raumgewicht ist eine komplexe Grösse,

die einmal von dem spezifischen Gewicht der Mineralkörner eines Gesteins, weiter von dem Porenvolumen desselben und dem Volumen anderer grösserer Hohlraume mit Gasen oder Flüssigkeiten abhängt. Die *Differenz* zwischen dem spezifischen Gewicht der Gesteinssubstanz und dem natürlichen Raumgewicht der Gesteinsvorkommens ist bei festen kompakten Gesteinen selbstverständlich am geringsten, bei lockeren unverfestigten Sedimenten oder bei blasenreichen Eruptiven am grössten. *Bei festen Gesteinem* mit dichtem Gefüge, wie etwa bei kristallinen Schiefern und Tiefengesteinen, wird diese Differenz oft unter 0, 1 bleiben, sollte aber trotzdem auch hier nicht vernachlässigt werden, schon wegen der häufigen Spaltenhohlraüme in diesen Gesteinen. Bei porösen festen Gesteinen, wie etwa bei manchen Sandsteinen, steigt die Differenz oft auf 0, 4 und mehr. In ganz extremen Fällen können Gesteine sogar leichter als Wasser werden (Bimsstein!). Bei unverfestigten Gesteinen ist die Differenz spez: Gewicht-Raumgewicht natürlich besonders gross. Das spez. Gewicht von Geschiebemergel ist z.B. etwa 2,66 und von Lehm etwa 2,58. Das natürliche Raumgewicht dieser Bodenarten ist dagegen nur mit 2,0 bezw. 1,0 zu veranschlagen. Die oberste gelockerte Ackerkrume oder Moorböden haben noch viel geringeres Raumgewicht. Ganz besonders gering ist dasselbe bei aufgeschütteten Gesteinen, wie die folgende zusammenstellung nach Macdonald zeigt:

Gewicht pro Volumeneinheit.

Gestein	Anstehend.	Aufgeschüttet.
Basalt	2,99	1,71
Granit	2,72	1,55
Sandstein	2,42	1,38

Diese Beispiele dürften für die Beurteilung der Dichte von Gesteinskörpern genügen.

Weniger bekannt dürften die für die *Gesteinselastizität* geltenden Zahlen sein, die für die Anwendung seismischer Methoden wichtig sind. Man misst bei diesen die Geschwindigkeit longitudinaler elastischer Wellen. Dieselbe würde, um einige Werte von gesteinsbildenden Mineralien zu nennen-theoretisch

für Quarz um 5000 m/sek	für Steinsalz 4500 m/sek
für Felspate um 6500 m/sek	für Gips 5500 m/sek
für dunkle Gemengteile 7000 m/sek.	für Kalkspat 6900 m/sek

betragen. Wir beobachten tatsächlich in lockeren Sedimenten Werte zwischen 600 und 2000 m/sek, in Kalk-und Salz-Gesteinen, sowie bei Eruptiven Werte zwischen 4000 und 6000 m/sek. Wir sehen also, dass bei den Gesteinen, die aus Lösungen auskristallisiert sind, Werte erreicht werden, die den theoretisch zu fordernden sehr nahe kommern. Bei unverfestigten mechanischen Sedimenten finden wir dagegen sehr grosse Differenzen zwischen den tat-

sächlich beobachteten und den theoretisch für die betreffende Gesteinssubstanz zu erwartenden Werten. Die Diagenese setzt die Geschwindigkeitswerte solcher Gesteine schon etwas herauf: Man erhält z.B. für unverfestigte Sande 600-1200 m sek. für feste Sandsteine dagegen schon 2000-2400 m sek. Aber erst gebirgsbildende Vorgänge und die damit verbundene mechanische Beanspruchung bedingt eine grundlegende Änderung der Gesteinselastizität. Man kann bei stark beanspruchten Trümmersedimenten (Quartziten und Tonschiefern) mit ebenso hohen Geschwindigkeitswerten rechnen wie bei Eruptiven. Für die elastischen Konstanten von Gesteinskörpern sind also besonders wichtig einmal die Entstehungsart (Ausscheidung aus einer Lösung oder mechanisches Gemenge) und weiter die spätere mechanische Beanspruchung.

Die *magnetischen* Eigenschaften eines Gesteins werden häufig nach dem Eisengehalt beurteilt. Das ist nur bedingt wichtig: Magnetit hat eine Susceptibilität die den Wert 1 überschreiten kann, während Limonit und Roteisen meist nur Susceptibilitätswerte zwischen 0,0001 und 0,0003 besitzen, die der Magnetisierbarkeit der häufigsten Gesteine bereits sehr nahe kommen. Man wird also bei stärker magnetisierten Gesteinen meist mit einem mehr oder weniger hohen Magnetitgehalt rechnen. Aber auch die Magnetitsubstanz ist nicht immer gleich stark magnetisierbar. An Einzelkristallen wurden in schwachen Feldern Susceptibilitäten bis 20 gemessen, während bei Kristallaggregaten selten mehr als 1 festgestellt werden konnte. Auch dieser Wert sinkt weiter, wenn die Magnetite mit anderen Mineralien gemischt vorkommen, oder chemische Beimengungen haben; magnetitreiche Eruptiva mit 10-20% Magnetit haben kaum je eine Susceptibilität von mehr als 0,01. Die Magnetisierbarkeit nimmt also rascher ab als der Magnetitgehalt. Sehr wichtig ist ferner der Titangehalt der Gesteine oder vielmehr die Art der chemischen Bindung des Titans im Gestein für dessen Magnetisierbarkeit. Turcev fand für einen Magnetit eine Maximalsusceptibilität von 1,6, für einen Titanomagnetit mit nur 3-4% TiO_2 nur 0,0003, Stutzer, Gross und Bornemann dagegen für einem Ilmenit wieder 0,03. Leider sind diese Dinge noch zu wenig erforscht, als dass man die hier geltenden Gesetzmässigkeiten in allen Einzelheiten kennen würde. Man weiss eben nur, dass das Titan die Magnetisierbarkeit eines Gesteines entscheidnd beeinflussen kann.

Die *elektrische Leitfähigkeit* der Gesteine der wir uns nun zuwenden wollen, hängt nicht allein von deren Gehalt an gut leitenden Mineralien ab, sondern sehr stark von dem Grad und der Art ihrer Durchfeuchtung. Hier spielt demnach die Grösse des Porenvolumens und dessen Inhalt eine grosse Rolle. Die meisten gesteinsbildenden Mineralien sind an sich Isolatoren, man findet aber im Felde und im Bergwerk höchstens in ganz trockenen Gebieten Gesteinspartien, die als absolute Isalatoren gelten hönnen. Man wird also die elektrische Leitfähigkeit natürlicher Gesteinsvorkommen nach ihrem Porenvolumen der Flüssigkeitsmenge, mit der die Poren gefüllt sind, und nach dem Elektrolytgehalt der porenausfüllenden Flüssigkeiten beurteilen

massen. In ariden Gebieten sind z.B. die salzigen Wasser ganz besonders gute Leiter. Die mit ihnen erfüllten Gesteine können bessere Leiter sein als Erzlagerstätten mit grossen Mengen derber Sulfiderze. Einige Zahlen sollen das belegen. Der durchschnittliche spezifische Widerstand (=reziproke Leitfähigkeit) ist:—

bei Einzelkristallen von Sulfiden 0001-1 Ohm pro ccm,
bei derben Sulfiderzen etwa 100 Ohm pro cmm,
bei einer 20% NaCl Lösung etwa 5 Ohm pro ccm,
bei einem Sandstein mit 26% Porenvolumen, das mit dieser Lösung erfüllt ist, etwa 30 Ohm pro ccm.

Dagegen:—
Normale, feuchte porenreiche Sedimente
etwa 10,000 bis 100,000 Ohm pro ccm,
porenarme, feste Gesteine
etwa 1000,000 bis 1,000,000 Ohm pro ccm.

Diese Zahlen zeigen den Einfluss der Gsteinsfeuchtigkeit zur Genüge. Daneben kommt es selbstverständlich auch auf den Gehalt an gut leitenden Mineralien im Gestein an. Hier ist weniger die Menge dieser Mineralien von Wichtigkeit als ihre Verteilung im Gestein. Sind dieselben unregelmässig und nicht in zusammenhängenden Partien im Gestein verhanden, so beeinflussen sie dessen Leitfähigkeit nicht so sehr, als wenn sie in, wenn auch dünnen, zusammenhängenden Lagen auftreten. Graphitschiefer z.B. mit dünnen Häuten des gut leitenden Graphits leiten oft besser als kompakte Erze.

An der Hand von einigen wenigen Zahlen habe ich zu zeigen versucht, eine wie geringe Rolle oft die Mineralzusammensetzung der Gesteine für die Beurteilung der physikalischen Eigenschaften von geologischen Körpern spielt. Sehr viel wichtiger ist z.B. vielfach das Porenvolumen und seine Ausfüllung, die Struktur, die mechanische Beanspruchung durch tektonische Vorgänge und vieles andere. Ich möchte zum Schluss allerdings hinzufügen, dass dies in der Hauptsache nur für die Gesteine der Erdhaut gilt. Je weiter wir in das Innere der Erde eindringen, um so einfacher und einheitlicher werden die physikalischen Verhältnisse: Die Gesteinsporen verschwinden mehr und mehr und ebenso ihre Ausfüllung mit Flüssigkeiten. Der wachsende Hangenddruck gewährleistet eine relativ gleichartige mechanische Beanspruchung u.s.f. Der Mannigfaltigkeit an der Erdoberfläche muss also in der Tiefe eine gewisse physikalische Einförmigkeit Platz machen.

74. THE FLORA OF VRYBURG DISTRICT IN RELATION TO THE GEOLOGY.

BY

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Introduction.

The Vryburg District is situated in the eastern fringe of the arid Kalahari in British Bechuanaland.

The observations herein recorded are the result of the extension of the intensive floristic studies of particular farms in the district in connection with the botanical aspect of the Lamsiekte investigations* carried out under the direction of the Director of Veterinary Services.

Most of the soils of the district are markedly phosphorus deficient; this is reflected in the vegetation, and consequently ultimately in the cattle which have to subsist entirely on this pasturage. It produces in them a considerable 'pica' or craving for phosphorus-containing substances (e.g. bones, dead carcase material, etc.). Hence the mineral deficient vegetable covering of the veld, forms the first link in the chain of the causation of Lamsiekte.

Consequently, the converse process, that is of conducting pica (craving) tests of cattle was used to detect the presence of phosphorus deficient pasturage on selected localities throughout the lamsiekte-carrying areas; and thus in conjunction with a study of the habitat conditions of the vegetation, to reveal the relation of plant to soil.

It was when the valley of the Dry Harts (Dwyka) was found to be a non-lamsiekte producing area, and further, that the flora on rocky outcrops differed so markedly from areas where the geological formation was hidden

* See the "Eleventh and Twelfth Reports of the Director of Veterinary Services, Part II, Union Dept. of Agriculture, Pretoria, 1927.

or masked by only a few feet of superficial deposits, that ecological studies were undertaken to ascertain the meaning of the evident relationships that were being found to exist between the flora and the physical features.

Consequently the surveys, limited hitherto to the pica investigations, were extended to include floristic studies embracing the whole district, from which data a vegetation chart was prepared.

Now, although similarities in the floristic composition of similar bare rocky habitats were noticed whilst engaged in the fieldwork and during the compilation of the map, yet no particular significance was attached to the data at the time. It was only when, months later, a geological map of the area was secured, that the striking consistency of the observed facts became evident.

A brief inspection of the map, especially of the difficult hilly area between Vryburg and Dry Harts stations to the east of Brussels, at once made plain that the general agreement of the charts could not be casual. Closer comparison, when the botanical chart had been drawn to the same scale, suggested an 'explanation'; which, if true, might prove of fundamental significance; i.e. That the distribution could be understood only if it were assumed that an intimate connection between the Geology and the Flora (in this area) were admitted.

The theory was at once put to the test and numerous difficulties presented themselves. This was particularly so in regard to the "masked" areas, i.e. where the underlying formation had been covered to some depth with superficial deposits. But when again it was recollected that most of the vegetation was shallow rooted, and also that the low rainfall could cause but little weathered derivatives from the hard rocks (e.g. Ventersdorp), to contribute to the surface soil in these areas, it became apparent that after a certain limit was reached the underlying rock need not or could not influence the surface vegetation.

Further fieldwork served to confirm this, and even to fix a rough value to the limit. That is, where a rock formation is covered to a depth of over four feet (in this district, chiefly with calcareous tufas and blown sand) over an area of at least several square miles, then the geology may have no relation to the flora. (Of course the hardness (or rather the 'weatherability,' of the formation and climate possibly make a considerable difference to this stipulation.)

Furthermore several anomalies in the recorded data appeared. But here again visits to the spots revealed imperfect charting in both the geological and botanical maps, and the serious anomalies disappeared. Rather did these subsequent visits, with the new angle of view now prominently before one, serve but to strengthen the concept with added data.

Many soil samples were taken throughout the district. Unfortunately the results are not available.

Before proceeding to compare the geological and botanical maps, however, attention will be drawn to some important features in the physiography and climate of the district.

It should be noted, however, that the area delimited is greater than the magisterial boundaries of the Vryburg District and includes some of the Transvaal in the east.

Geology.

The geology of Vryburg district, as given in the map was compiled from Sheet 50 of the Cape Geological commission, (1908), to which has been added on its eastern side, a considerable section drawn from information supplied by the Director of the Geological Survey and now embodied in the map of the Union of South Africa.

The map is largely self explanatory, and shews the farm "Armoedsvlakte" on which the intense botanical studies were undertaken for sixteen months, together with the more important of the farms which were tested for pica in the Lamsiekte investigations and on which special botanical surveys were continued for some years.

Topography.

The relation of the formations to the physical features is not apparent from the map but is of considerable ecological importance.

The eastern portion of the area is an undulating region of rocky hills and plains with an average altitude of 4,000 ft. These low ranges include the Koranna and Morokani Rands, which lie in a general north and south direction and are mainly constituted of outcrops of the *Ventersdorp* igneous series. Thus to the east of the Vryburg-Taungs railway line, the *Ventersdorp System* is very conspicuous. Where, however, it is shown to the north of Vryburg it is by no means conspicuous; in fact it is for the most part completely hidden by the superficial deposits of varying depths of red sand or limestone tuffs, and the country is absolutely flat and unfeatureless.

The surface soil, however, is largely composed of an admixture of the weathered derivatives of the underlying rock together with the superficial deposits.

Where this has been observed the influence on the vegetable covering has been considerable, so that, although the flora is not the same as on the pure outcrop, yet it is more closely related to that flora than to the contiguous areas where the superficial deposits cover the formation for depths greater than five feet.

The next most important feature is the NGAAP Plateau, rising from 50-150 ft. above the general level of the pene plane, and forms perhaps the most conspicuous element in the geology of the district. The formation is *dolomite* of the *Transvaal system*, and the rocks ('Jonas Klip' of the area) frequently outcrop especially on the east, bordering the Dry Harts River valley where the escarpments are rather sharply defined.

The surface itself is flat and unfeatureless, and is usually covered with a very thin layer of blown (Kalahari) sand and calcareous tufa. It forms a watershed between the Dry Harts and Kuruman Rivers, but no permanent water is found on its wide expanse (except in deep wells and springs in fissures), the stormwater courses being dry throughout the greater part of the year. In the north it merges imperceptably into the general plain of the Arid Kalahari.

A very slight semi-circular ridge marks the occurrence and most often an outcrop, of the *Black Reef Series* and its associated basic rocks, so that here and there a low hill perhaps 100 ft. high and half-a-mile long may occur. This ridge carries an Andropogonous flora of middleveld affinities, so that it has been classed with the flora occurring on the masked Ventersdorp series (i.e. north of Vryburg.)

In the north-west corner of the district, and to some extent in the north and north-east, slight outcrops of the 'fundamental complex' or *Gneissose* rocks occur; but the area is so flat and deeply covered with blown sand that the underlying formations are completely hidden. The flora is arenaceous and typical of what is known of the great interior of the Kalahari.

The Valley of the Dry Harts is a long depression extending from above Vryburg in an almost due S. direction to beyond Taungs, and somewhat abruptly separates the Ventersdorp rocks which form the eastern escarpments from the steep western fringes of the NGAAP. It is interrupted between Dry Harts and Vryburg railway stations by an outcrop of the *Black Reef series* known as the Middle Rand. The Valley consequently forks around and about these outcrops at Verona and Brussels to isolate these rocks between the *Ventersdorp* and *Campbell Rand* (*Dolomite*) series to form a group of hills and ridges whose geological constitution thus may contrast somewhat markedly and suddenly. It is on these different sharply defined contiguous formations that the flora so typically reflects the geology.

The Valley continues above Vryburg in a north-easterly direction. As a whole the valley covering is comprised of deep alluvial soil consisting mainly of remnant beds of the *Dwyka* formation. To this much has been contributed by the weathered products of the fringing rocky escarpments on either side.

The soil is thus seen to be different from any other soil in the district, and indeed, of the region. As has been previously referred to, it is only in this valley that the few non-pica producing (Lamsiekte-free) farms occur,

although all the farms are not free. Those in which the highly-weathered products of the *Ventersdorp system* are admixed with the *Dwyka* derivatives are found to be quite pica-free, and the grassy covering more dense and specialised. The chief grasses are *Digitaria eriantha, Panicum coloratum* and *Schmidtia bulbosa.*

The valley carries a peculiar flora mainly with middleveld affinities to which some NGAAP constituents have contributed. But in the north-east, where the influence of the Ventersdorp system is largely lost, it merges definitely into the subtropical bushveld from the Lowveld above Mafeking in the north-east.

One variant affecting the flora which may confuse the observer, is the influence of the limestone tuffs. Where these occur they form a hard impenetrable substratum. The uppermost layers are oxidised into a hard crust from 2-6 inches in thickness which is quite impervious to moisture. Consequently, not only is the underlying formation hidden (i.e. unable to contribute to the surface soil), but no soil moisture is able to reach the roots from below. In addition, the salts formed in the surface soil tend to accumulate, and their concentration is usually very great.

The effect is to make such impositions, that only a special flora can subsist on it. It is fortunately easily recognisable but must not be confused with that 'determined' by (i.e. found upon) a geological formation.

Such soils need a large excess of water, (i.e. a well-distributed, heavy rainfall) in order that their mineral constituents may become available to the vegetation. They are then usually found to be far more fertile than any of the soils on the rocky outcrops of the district.

Unfortunately it is this very lack of an adequate well-distributed water supply which makes plant life here so difficult and largely determines the stunted character and life-forms of the flora of the whole region.

Drainage.

As has been mentioned, permanent water is exceedingly rare in the district. The main drainage is from the north in the stormwater course of the almost dry Harts River depicted in the eastern third of the map. As can be seen this channel, with many of its tributaries, has been cut mainly in the softer *dwyka.*

One branch from the north-west, comes from the interesting farm "Lochnagar" and contains a trickle of permanent water. This arises from a deep cavity over 90 feet in depth and about 100 yards in diameter) where a fault cuts through the small outcrop of the Black Reef series and into the dolomites to the north. Hence we see the rare phenomenon of a reed swamp *(Phragmites communis)* with water lilies (*Nymphaea stellata*) in the midst of a most arid area. (See Plates 1 & 2).

Equally interesting is the belt of trees (*Acacia Karroo*) from 70-100 ft. wide but about 10 miles long which marks the whole course of the fault, and forms the most conspicuous feature of the landscape. The *Acacia* trees are abnormally high (see Plate 2), varying from 20 to 60 ft. and vividly green; evidence enough that their roots are in constant contact with an abundant water supply. These characteristic belts of trees are known locally as "Aars," and not only usually occur at faults especially on the dolomite (vide the south-western portion of the map), but have frequently served to apprise the geological surveyor of the presence of a fault where none was apparent from the superficial evenness of the plain.

Other occurrences of springs were noted on the farms Progress, Geluk, Damplaats, Dwaalvlakte and Pudimoe.

Permanent water is found where the course of the Dry Harts enters the Harts river near Taungs to continue their southward course to the Vaal River.

Climate.

The average annual *rainfall* over the district is about 15 inches spread over the five summer months, on 43 rain days, February and March having the heaviest precipitation.

The prevailing *winds* are from the north-west, and most farmers have installed windmills which operate at an average wind velocity of 15 miles per hour. These winds, very severe in the driest months of July-September, transport enormous volumes of dust from the Kalahari proper on to the district, steadily covering the area. This factor alone, through time, has had a profound influence on the distribution of the flora as found to-day.

The important thing about the *temperature* is the mean seasonal range of air values which is ± 33° F., but the means for the driest winter months may be over 40° F., whilst the extremes for the same period may be as severe as 60° F. This taken in conjunction with so low an average *relative humidity* as 53, which in the three hottest months (November-January) and the three coldest months (June-August) is nearer 40; as also the fact that almost the maximum undiffused sunlight is recorded (with consequent high insolation), the conditions for plant growth are almost as severe as obtains in the heart of the arid Kalahari itself. The difference there in the main is almost entirely due to the progressive intensification of the climatic factors, rather than the edaphic factors.

Ecology.

The North-Eastern Lowveld.

In the N.E. corner of the district will be seen a small tongue of the Low Veld flora which has come down so far south from the Valley of the

Limpopo. *Combretaceae,* elsewhere absent in the district and characteristically absent from the Arid Kalahari, are frequently found particularly *Combretum imberbis* var. *Petersi* (Hardekol) and *Terminalia sericea.* With these trees occur the Beukenhout (*Faurea saligna*), which also extends right down the Dry Harts Valley and is occasionally found on the southern N'Gaap; the Moroola (*Sclerocarya caffra*). *Mundulea suberosa* on the rocky portions, with *Dichrostachys nutans. Dombeya rotundifolia, Combretum holosericeum, Cadaba macrocarpa, Strychnos pungens,* occasionally *Acacia haematoxylon,* and even one or two species of *Ficus* may be found. The grasses are tall and lounging of the *Andropogoneae* series, but of which the *Paniceae* are the most prevalent forms.

The Middleveld Flora.

Almost the whole of the Eastern portion of the district about longit. 25° including that portion which forms the western limit of the Transvaal Highveld, here known as Middleveld, belongs to the Banken Veld flora of Pole Evans.[1] This hilly country is characterised by the tall Andropogonous grasses (Euandropogoneae section), *Hyparrhenia Spp., Schizachyrium semiberbe, Andropogon Spp., Cymbopogon excavatus, Heteropogon contortus, Elionurus argenteus;* and a great number of Series II, especially the genus *Eragrostis. E. chalcantha,* and *E. curvula* are characteristic in the proportions in which they occur, although such cosmopolitan species as *E. plana, E. superba, E. brizoides, E. gummiflua* and *E. major* are by no means unimportant. In fact the large genus *Eragrostis* may be used in the same way as the *Acacias* (Leguminosae) and *Senecios* (Compositae) in defining (by the kind and proportion of species present any ecological formation in Southern Africa) except the Namib which is conspicuous for the absence of almost every kind of herbage.

The Andropogonous-Veld Flora.

The soils derived from the *Ventersdorp* system are arenaceous and somewhat acid, and even where softer rocks occur, as on the Koranna Rand and Morokani Rands, and the *Black Reef* and quartzite (Pretoria) Series of the Transvaal System (e.g. Middlerand and the ridge extending from Vryburg to beyond the farm Hassforth), none of the soils are alkaline as are those of the N'Gaap and even those of the Dry Harts Valley.

The *Andropogoneae* grasses seem to be addicted to these acid soils, and a considerable intrusion of these grasses occurs to the north of and around Vryburg, E. & W. Together with these grasses, of course, a considerable number of hardy Middleveld herbs and shrubs also occur. Special mention should be made of *Acacia robusta, A. litakunensis* and the rare *Senecio burchellii.*

In the S.E., beyond the Lange Rand at Taungs (which rand is Andropogonous) the veld is characteristically that of the N'Gaap, even although the underlying rocks are *Ventersdorp* and *Dwyka*. The surface, however, is largely covered with tufaceous limestone just as is the N'Gaap and here again the surface soil is largely the determining factor for the flora carried.

This same point is brought out on the farm Lochnagar, where the reverse condition obtains. Here an outlier of the *Black Reef* Series with the associated *Pretoria* series of quartzitic rocks situated right in the midst of the N'Gaap dolomites entirely alters the surface soil character, i.e. deep reddish sand- and the flora carried is *Andropogonous* in type.

Hence it appears that this "Andropogonous Veld" within the confines of the Arid Kalahari, must be regarded as an intrusion due to local edaphic conditions,—the hardier forms of the Middleveld flora persisting,—and taking their place, and even successfully competing with such typical Arid Kalahari grasses as *Aristida uniplumis*, *A. ciliata*, *Schmidtia bulbosa*, *Fingerhuthia africana*, *Chrysopogon serrulatus*, and *Anthephora pubescens*.

The chief Andropogoneae in this area N. of Vryburg are *Hyparrhenia hirta* (not found on the N'Gaap); *Schizachyrium semiberbe* (not found S.W. of Vryburg): an unusual preponderance of *Andropogon amplectens*, *A. schirensis*, *Cymbopogon excavatus*; *Heteropogon contortus*, is particularly abundant; *Trachypogon plumosus* (not found on N'Gaap), and of course, *Elionurus argenteus*.

Chrysopogon serrulatus must be classed with this group, for although it is found even over 5,000 ft. in the Highveld on Limestone rocks, yet in the Arid Kalahari on the eastern borders, it is the subdominant, and almost the leading species. Only in the Pilandsberg has the writer seen the proportions of this most useful perennial grazing grass attain to those of the Arid Kalahari.

Similarly *Themeda triandra*, the 'Rooi Gras,' is a tropical grass which has invaded Southern Africa from the north, and has penetrated far south, invading chiefly the eastern and central regions. But the greater part of the south western Karroos and the central and more western portions of the Arid Kalahari have so far proved ecological barriers too difficult to traverse. There is considerable evidence, however, that it is making a steady advance south-westwards; and the N'Gaap, which carries a more recent flora than that of the Karroid Plateau to the S.E. of it, has been more thoroughly invaded by this grass. In the N.E. portions of the N'Gaap (i.e. as on the farm Armoeds Vlakte), it is now the leading species, to which position it has long attained in the Highveld and Eastern Grassland regions of Southern Africa.

THE N'GAAP FLORA.

The N'Gaap is a region of low bushes 6-12 ft. in height, rarely more, and tufted grasses. The characteristic feature is the sparse colonisation of

the soil, bare areas of a foot or more isolating each tuft; to this must be added the extreme xerophytism and dwarfing of almost all forms; and, as one might anticipate, the number of prostrate forms.

In the south, the bush is relatively denser and taller and composed chiefly of *Tarchonanthus camphoratus, Acacia detinens, Olea verrucosa, Grewia cana* with species of *Lycium* (especially *L. oxycladum*), *Euclea* and *Boscia.* In this part, the grasses *Enneapogon scoparius* and *Anthephora pubescens* are the predominating types, with *Aristida uniplumis.*

In the central portion *Grewia cana* increases and *Acacia stolonifera* large replaces *A. detinens,* and the low shrub *Rhus tridactyla* forms dense local communities. *Enneapogon* finds a serious rival in *Fingeruthia africana* and *Chrysopogon serrulatus,* whilst *Themeda triandra* and *Digitaria eriantha* are in the rôles of Leading-, and Subdominant species.

In the north-east *Grewia cana, Rhus tridactyla, Tarchonanthus* and *Royena pallens* really characterise the veld in the bush types, whilst *Themeda triandra* and *Chrysopogon serrulatus* are the principal grass types. *Olea verrucosa* has disappeared. Occasionally, but quite typically, one finds solitary trees of *Rhus lancea* affording evergreen shade to all stock.

Throughout the N'Gaap the ubiquitous *Acacia karroo* is to be found, and in damper habitats *Acacia giraffae* occurs, although never of the magnificance in size and graceful habit that they attain in the Sand-Kalahari.

The Sand-Kalahari Flora.

The north-western portion of the N'Gaap, as one would expect, is much more sandy. The flora consequently gradually alters westwards chiefly in percentage proportion, only a few species dropping out and a small number of new ones entering the composition.

Thus *Aristida uniplumis* rapidly becomes the dominant and leading species, *Themeda* dwindling: *Schmidia bulbosa* becomes greatly in the ascendant, with *Aristida ciliata* (new entrant), *A. congesta, A. vestita; Eragrostis pallens* and *E. bechuanica; Anthephora pubescens.* The other notable dwindlers are *Digitaria eriantha, Fingeruthia africana, Eragrostis lehmanianā, E. superba; Sporobolus fimbriatus.*

Beyond the slight ridge formed by the Black Reef seriēs at Hassforth (separating the N'Gaap from the Gneissose rocks) and N.W. of the junction of the Ventersdorp with the Gneissose beyond the farms England and Zoetlief, the deep sand begins almost dramatically.

Here *Acacia giraffae, A. robusta* and occasionally *A. Karroo* are quite dominant and often are the only trees. The sand is very poorly colonised in grasses. These are mainly *Aristida ciliata, A. uniplumis, A. brevifolia, A. obtusa; Eragrostis pallens,* rarely *E. spinosa,* and occasionally *Stipa tortilis.* Large patches of *Enneapogon scoparius* are liable to occur on sloping ground; and *Panicum coloratum* where the sand is more mixed with clay (chocolate

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PLATE 2.

soils.) *Boscia foetida*, Schinz., *Parkinsonia africana*, *Sond.* and *Pappea capensis* E. & Z. occur as isolated trees—the 'Witgat' (*Boscia*) characteristically occupying the summits of dunes.

The Dry Harts Valley Floral Complex.

Returning to the Dry Harts Valley, the flora is much mixed. As has been previously mentioned the soil is very deep and alluvial, and apart from the *Dwyka* tillite, it is being constantly added to by the erosable elements from the steep embankments on either side (the N'Gaap on the west and the Ventersdorp on the east), except in the north where the Black Reef and Pretoria Series replace the Ventersdorp rocks on the east and centre.

The greater part of the bottom of the Valley is moist, and from just S. of Brussels carries permanent water, which at Pudimoe opens out into a broad Pan. The valley is so peculiarly situated that rainwater drainage from the west, north and east moves towards this Valley and often deep channels have thereby been cut into it. In a great many instances these occur at the junction of two geological formations.

Whether this fact has played as great a part in bringing about the complexity of flora of the Valley as the other factors, (e.g. greater average humidity, greater amount of soil moisture, protection from the dry, and often sand-laden winds), only future work in this area can determine. But it is worthy of note that each class of rock bears its own flora on the heights in and adjoining the valley. This is well brought out by the surveys on the farms Verona, Vleiplaas, Borthwick, Hartklip, Damplaas, Paradys and Vreesniet.

Low Veld bush is able to exist far down the valley, such as *Mundulea suberosa*, *Dichrostachys nutans*, and large trees of *Zizyphus mucronata*, *Celtic rhamnifolia* and *Trema bracteolata*.

Middleveld bush such as *Rhus viminalis*, *Acacia litakunensis*, *Euclea undulata*, *Strychnos pungens*, *Boscia transvaalensis* and *Gymnosporia buxifolia* flourish on the slopes of the *Ventersdorp* and *Black Reef* outcrops.

Where the gorges open out *Tarchonanthus camphoratus*, *Grewia cana*, *Acacia giraffae*, *A. Karroo*, *A. robusta*, *A. litakunensis*, *Lycium hirsutum* predominate.

Old residents of the Valley relate that 40 years ago *Acacia robusta*, *Burch.* formed a dense parkland from Brussels to Border, which was ruthlessly cut down to provide timber for the Kimberley Diamond Mines. There is abundant evidence of the existence of such 'bush,' and to-day a small section about Taungs has been preserved by a native chief.

The grasses, however, shew perhaps the most astonishing features of the flora. The leading species on the soils above the Ventersdorp and dolomite formations is *Themeda triandra*. In the valley (Dwyka) however this grass is a great rarity, and is often entirely absent. The ridge summits

where the formations are exposed, of course, are densely colonised by it. Its place in the valléy is largely taken by the Low Veld grass *Panicum coloratum* (No. 8986) and Highveld grasses such as *Chloris virgata, Tricholaena rosea* and the large 'Krull Gras' (*Eragrostis Sp.*) occupy sub-dominant positions.

On the slopes on both sides of the valley, local communities of *Schmidtia bulbosa* with *Aristida unimplimus* and *Eragrostis atherstonei* (wiry-leaved variety) may entirely usurp the veld; in other patches *Digitaria eriantha* and *Eragrostis superba* are predominant.

Amongst the shrubs (e.g. *Grewia cana, Acacia karroo*) the low veld grass *Pennisetum cenchroides* is very common and much sought after by stock and game. It occurs nowhere else in the district.

The valley bottom is more densely grassed than elsewhere in the district. As has been previously mentioned, the grass *Panicum coloratum* is the leading species on the drained soils. Amongst it are frequently found plants of Salsola *tuberculata,* Fenzl., the "Brak Ganna." (See Plate 4).

Where permanent water is found, as at Pudimoe "Pan," *Echinochloa holubii,* a tall grass which occurs in small proportion on all impervious pans throughout the district, is here *completely* dominant. At its base is the newly described grass *Cynodon transvaalensis,* Burt Davy. Where the ground is not quite so moist, *Eragrostis bicolor* and *E. burttdavii* predominate. Outside this zone *Eragrostis lehmanniana* then succeeds, to be followed by *Chloris virgata,* and then *Panicum coloratum.*

In the moister parts (*Echinochloa* zone) are to be found many species of *Crotalaria* (*C. distans, C. nubica, C. abyssinica*) and in the *Eragrostis bicolor* zone the poisonous *Moraea polystachya.* In the *Panicum coloratum* association, the poisonous *Dimorphotheca Zeyheri* is found in small proportions.

Summary.

In conclusion, then, one may postulate:

1. That where the geological formation outcrops over a large area in a locality it is liable to carry a flora so peculiar and characteristic as to be readily distinguishable, in its principal constituents, from the flora of an adjoining different rock in the same climate.

This is well seen in the flora of the group of hills of exposed rocks of different composition between Vryburg and Taungs.

2. That where the underlying formation is masked over a large area by superficial deposits of at least *four feet* in depth (possibly deeper in the case of a soft, easily weatherable rock, in a moister climate), the nature of the geology may have no influence on the surface vegetation.

This is exemplified in the north-west and south-west corners of the botanical chart.

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PLATE 4.

Where the rock is but shallowly covered and its derivatives contribute to the surface soil, a variable flora will result, which may or may not bear some relation to that on the pure outcrop of the formation.

(e.g. *Ventersdorp* system north of Vryburg)

3. That geological faulting, accompanied as it usually is by sharply contrasting variations of rock, soil, water accessibility, and such factors, but where the physiography has not been sensibly altered, may be discernable by the suddenly altered character of the vegetation upon it.

This is well seen in the "Aars" on Lochnagar and many other such Aar-marked faults in the south-western N'Gaap.

4. That therefore ecological plant geography may be of material assistance to the geological surveyor and soil chemist; and, as far as macroscopic geological surveys may be made from the air, the vegetation properly used may be of considerable value in charting well defined geological formations.

(*NOTE*: The plants collected in the course of the botanical surveys in the regions are preserved in the Ecological Herbarium of the Division of Veterinary Services at Onderstepoort, Pretoria, where they may be consulted. A duplicate set is also to be seen in the National Herbarium, Pretoria.)

EXPLANATION OF PLATES.

Plate 1. Reed Swamp Association in the midst of the eastern Arid Kalahari, the springs appearing about a fault in the *Black Reef* Series over the Dolomite.

Rocks: Quartzites of Black Reef Series on right, covered with tufaceous limestone (middle distance), upon which is blown sand (Kalahari).

The *fault* is marked by the 'Aar' of tall trees of *Acacia Karroo* behind the reeds.

Plants: *Phragmites communis, Trin* on left; *Nymphaea stellata, Willd.* centre foreground; and on right *Juncus bechuanus*, Schönl (Mogg No. 8647, Sp. nova); on left foreground, Juncus Sp. (Mogg No. 8437, Sp. nova).

Photo by A. O. D. Mogg. Farm Lochnagar, March, 1921.

Plate 2. The reed swamp (*Phragmites communis, Trin*). a rare occurrence in the Arid Kalahari, about some permanent springs from the underlying dolomite.

The belt of Sweet-thorn (*Acacia karroo, Hayne*) seen in the left background, conspicuously marks the geological fault on the farms Aarbosvlakte and Lochnagar (See Vryburg map). This belt of trees, locally known as an "Aar," rises abruptly from the plain to the unusual height of 25 ft. extends in a perfectly straight line on either side for 10 miles, but is at most 50 feet wide. It is thus a remarkable feature in an otherwise treeless region.

Photo by A. O. D. Mogg. March, 1921.

Plate 3. Transition from *Black Reef* to *Dwyka*. In the foreground is seen *Boscia transvaalensis, Pest.* growing out of a *Grewia cana*, Sond. thicket. On the right *Acacia robusta*, Burch. a very typical plant of the valley, dominant at Taungs. On left mid-distance *Rhus viminalis;* on higher slopes, *Dichrostachys*, [illegible] and *Mundulea*.

Photo by A. O. D. Mogg. Morokani Rand, March, 1921.

PLATE 4. The flora on the Dwyka in the valley showing *Salsola tuberculata Fenzl.* "Brak Ganna" in amongst a pure growth of *Panicum coloratum, Linn.* at Dry Harts Station.

Photo by A. O. D. Mogg. March, 1921.

PLATE 5. A view of the tongue of the Dry Harts Valley bush (on Dwyka) along the Pudumon River separating the Koranna and Morokani Rands (*Andropogonous* flora on these Ventersdorp laval outcrops).

The white shrubs are *Tarchonanthus camphoratus, Linn.* var. *litakunensis, Linn.* whilst the dark Valley bushes are *Zizyphus mucronata, Willd., Acacia robusta, Burch., A. giraffae,* Burch., *A. karroo, Hayne,* and the lighter smaller bush, *Grewia cana, Sond.*

Photo by A. O. D. Mogg. Farm East Verona; Sunrise, March, 1921

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PLATE 5.

75. A PRELIMINARY ACCOUNT OF THE FLORA OF PRETORIA IN RELATION TO THE GEOLOGY.

BY

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Introduction.

Some fifteen months ago a study of the flora of the southeastern portion of Pretoria environs was undertaken, an area comprising some thirty-five square miles of territory. The region was unfamiliar and was found to afford some striking contrasts to the more familiar flora to the west and north.

Physiographically the country is mostly mountainous, except for plains in the N.E., and S.W. corners and comprises a much faulted portion of the Time Ball hill range where it adjoins the dolomites of the Pretoria Series of the Transvaal system. It includes Klapper Kop with its westerley outlier Schanskop, as well as Strubens Kop (East Fort) which is a detached segment of the Daspoort Range.

The initial field work revealed such a complex of difficultly-related communities, that it was decided to obtain a concept of the distribution of these habitats, and if possible, the relationships of the communities, from the air.

When the preliminary flight* was made however, it so influenced my future work on the area that brief reference must be made to it here.

But before doing so, one great difference between the flora of the southeastern area from that of the north and west had attracted my attention, and that was the great belt of *Protea caffra* on the southern slopes of

*By kind courtesy of the Director of the S. African Air Force who not only placed a machine and pilot at my disposal but in addition took many photographs of selected hillside communities, some of which are reproduced herein.

Klapper Kop and their great abundance and somewhat puzzling distribution in the remainder of the area.

This species is almost absent from the Magaliesberg range and occurs but infrequently on the western portion of the Daspoort range.

It was determined, therefore, to take particular note of this distinctive form.

Aerial Survey.

The course charted for the pilot was a zigzag one to traverse the whole area.

Commencing at Ashbury Siding (over the dolomites) in a north-easterly direction over Klapper Kop to Koedoespoort, the plane passed over five ranges, traversing the nine miles in seven minutes.

That is, beginning with an initial strong impression of a broad belt of *Proteas* just below the southern summit of Klapper Kop, this observation was repeated for the five distinct ranges at intervals of considerably less than two minutes, creating a profound impression in my mind, confirmed and deepened throughout the remainder of the flight.

The circumstance could hardly be casual, for it was perceived from the perfectly constant position in which the Protea was found on each of the southern strike crests that it occurred just *exactly* where the diabase intrusions or equally, the softer pink sedimentary shales reached the surface adjoining the harder quartzite.

When the middle of Klapper Kop range was reached on the return journey, a belt of *Protea caffra* was observed on the North, East and South aspects closely investing the crest of a conspicuous magnetite ridge where the formation had been twisted along a fault plane to lie in a curved North, East and South position. Similarly on the West slopes of Klapper Kop the two parallel bands of the outcropping magnetite had been bent from the South thence Northwest to North. The *Proteas* similarly followed these formations closely and were thus exposed on the West and Northwest aspects. In each case they were confined to the limits of the outcrops of the diabase and pink shales.

This constant position of the Proteas on the diabase and contiguous soft pink shales, and its apparent avoidance of the harder rocks, was observed throughout the flight; and my vivid impression of the first few minutes were confirmed the more, as the complexly faulted and contorted areas were traversed.

That is (1) neither *aspect*, nor *angle of slope*, nor *altitude* seemed to count nearly so much, if at all, as the *nature* and *character* of the underlying geological formation either outcropping or within 12" of the surface. (2) If this seemed true for *Protea*, it was at least apparently equally true for *Chrysophyllum* and its associates on the harder rocks.

Much further stimulus to pursue this theme of a possible connection between the geology and the flora was given at the end of this first flight.

Proceeding from Ashbury Northeast to Schanskop a group of small *Proteas** were observed in the midst of an outcrop of the very hard dolomitic chert at the *bottom of the valley.* This observation proving incompatible with the former deductions and rendered more incredible by the whole hillside of *Protea caffra* in full view covering the south slopes of Schanskop a few hundred yards above, signal was given for the plane to descend.

From 100 ft. their indentity as *Proteas* was established; the approaches were marked, and the plants easily traced within half an hour of the descent. Close examination proved them to be of a dwarf hairy species (*Protea Hirta, Klotsch*) hitherto unrecorded for Pretoria district, and later found to differ entirely in their edaphic requirements from *Protea caffra.*

Before these results can be presented, however, it will be necessary to give a brief account of the Topography and Geology of the area.

Topography.

The Klapper Kop range lies in a northwest to southeasterly direction diagonally across the area. Parallel with it, and to the north (scarcely a mile distant from summit to summit), lies that portion of the Time Ball Hill range, from which Klapper Kop has been faulted off. To the south of Klapper Kop range, under a mile away, and almost parallel to it, the dolomites rise into the high tableland forming the southwest section of our area.

In the extreme southeastern corner of the area, the Klapper Kop range is again faulted and turned southwards right into the dolomites.

This bending southwards of the Klapper Kop section, followed by other discontinuous portions of the Time Ball Hill series, has a considerable bearing upon our subject. For these walls of high level ridges extending into the water-containing dolomites form important watersheds, so that drainage of the area is on one hand to the west along open valleys to Groenkloof Valley ** giving rise to the Apies River, most of which is diverted to the water supply of Pretoria.

On the other hand drainage is north and northeast down three important wooded ravines or kloofs (1) Waterkloof ravine (2) Wolvekloof Ravine, and (3) Garstfontein ravine. These three streams bend round to meet in the northeast corner of our area where they pass through the Daspoort range at Fairy Glen (near Strubens Kop), and are then known collectively as the

*No other plant in the area really looks like them. It was only because in their dwarf habit they looked different from young plants of *Protea caffra*, that additional assurance was insisted upon.

**(Botanically described by Miss I. C. Verdoorn).

Hartebeest Spruit, a tributary of the Pienaars River. It is of ecological importance here to note that the Hartebeest Spruit and Pienaars River, travel northwards for some 40 miles in close association with the large Elands River, an east flowing stream, whose course and numerous tributaries interdigitate themselves in contiguous valleys with those of the Pienaars. The Elands and Wilge Rivers pass through that mountainous semitropical portion of the Transvaal which lies northeast of Pretoria district. The flora of the eastern ravines of our area are related through these rivers to that semitropical flora.

The average rainfall may be taken as 26 inches per annum, whilst the mean maximum temperature for the three summer months is 80°F, the mean minimum temperature for the three winter months being 42°F. What is of considerable importance, however, is that in these driest winter months the *diurnal range* may be as much as 42°F.

The highest point in the area is Klapper Kop 5,055 ft., the dolomite flats are about 4,700 ft., Strubens Kop 4,760 ft., whilst the valleys are mostly 4,600-4,400 ft.

Geology.

A full account of the geological formations of the district must be looked for in Hall's explanation of his geological map of Pretoria.*

However, it will be necessary here to give a brief sketch of the main features in order to indicate the relationship between the structure and the physiographic features which form the habitats of the plant associations with which we are concerned.

The formations are both sedimentary and igneous. Of these the sedimentary rocks occupy by far the greatest proportion of our area, and are constituted of the Transvaal system comprising the Pretoria series of *Quartzites* and *Shales*, together with the Dolomite formation of Dolomites and Chert. The intrusive igneous rocks with which we are concerned are (1) the *Norites*, which form the southern margin of the Bushveld Plutonic Series. (2) *Diabases*, intrusive in the Pretoria Series. (3) *Diabases*, intrusive and extrusive, in the Dolomite. These, although occupying a relatively small proportion of the area, are nevertheless of great ecological importance.

The Pretoria series, in their least disturbed position to the west of Pretoria, are a little over five miles in thickness from south to north, and consist of soft thinly bedded shales interspersed at approximately 2½ mile intervals by bands of hard massive quartzites. In course of time these rocks have undergone progressive erosion, so that the shales have been "worn

*A. L. Hall, "Geology of Pretoria and neighbourhood," Government Printer Pretoria, 1905, also the revised map just published by the Geological Survey, Pretoria, (1929).

down" to valleys, leaving the harder quartzites as a series of protruding ridges 300-700 feet above the plain, and extending for hundreds of miles in a general easterly and westerly direction.

It is this impression of a regular alternation of lines of hills and gentle valleys which forms one of the most characteristic features of the neighbourhood of Pretoria and led Pole Evans* to describe this as the Banken Veld region.

The uppermost of these *quartzite* ridges at about 600 ft. above the valleys, is known as the Magaliesberg range, and consists of massive rocks at least 700 ft. in thickness; in the middle or Daspoort range, the quartzites are only about 250 ft. in thickness, whilst in the lowermost or Time Ball Hill range (comprising the formation in the greater portion of our area), the quartzites occur as a series of narrow bands of variable thickness, sandwiched in between the shales, i.e. 25 ft., 16 ft., 10 ft. and etc. gradually becoming closer together as they become narrower. Here it must be mentioned that two of these bands contain such a quantity of iron (Haematite) that they are very hard and difficultly erosible, and may easily be distinguished from the other or white quartzites by their dark chocolate purple colour. Where they outcrop they bear a flora peculiar to them.

The *shales* consist of thinly bedded, finely grained soft rock, varying considerably in colour, the prevalent tints being pale-grey to yellow, but red, purple, and black shales are not infrequent. They occur in a series of varieties from south to north, and of several miles in thickness between the ranges. At a depth of 50 ft. or more they are greyish-blue and relatively hard, but towards the surface they become considerably softer, comparatively easily erodable, and generally readily penetrable by roots. Exceptions occur in (1) harder flagstone varieties outcropping in the south-eastern area, and (2) in those metamorphosed by contiguous igneous intrusions.

Below the Klapperkop shales on the south, the *dolomite* formation occurs. These consist of massive lime-stone rock of great thickness, and the formation continues for many miles south of our area.

The dip of the strata of the Pretoria series is on the average northwards about 30° although locally it may be very variable.

The part played by the Igneous rocks must now be briefly referred to.

The Norite is confined to a long narrow strip of country about 3 miles north of the Magaliesberg range and topographically is recognisable as a detached group of rugged outcrops known as the Pyramid Hills. No such rocks occur in the southeast of Pretoria, but their vegetal covering must later be referred to.

The Diabases are very important, however. These are extensively intrusive into the Pretoria series as great sheets of variable thickness from a

*Dr. I. B. Pole-Evans "The Veld and its Resources"—Presidential address to the South African Association for the Advancement of Science, 1920 (Journal 1921).

few feet up to as much as 500 ft. in breadth, and have penetrated wherever the structure of the Pretoria Series was weakest. Thus one finds it (1) between the quartzite and the norite (2) between the quartzites and shales, often on both faces in the three main ranges; (3) between the different series of shales in the valleys. It is also intrusive into the dolomite and extrusive between the dolomite and Time Ball Hill series.

From the ecological point of view it is important to note here that although the diabase is a hard rock, it weathers comparatively easily into a red, friable, surface soil easily penetrable by roots.

These characteristics enable it to be readily identifiable from the nature of the deep-rooted vegetation which is able to subsist on it more easily, often, than on the shales.

To give an idea of the extent of these intrusions HALL mentions* that 12 such intrusive sheets occur on the Pretoria map.

So far our attention has been confined to the "normal" or least disturbed areas to the west of Pretoria. The east and southeast, however, have been subjected to much modification.

Subsequent to the intrusions of these diabases, considerable volcanic activity manifested itself in the northeast of Pretoria district as the result of which the Premier Diamond Mine pipes occurred, together with some volcanic breccia at Derdepoort.

Considerable earth movements accompanied these eruptive forces whereby the formations in Pretoria were subjected to "the operation of some powerful dislocating tangential stresses, acting along a northeast and southwest line, which resulted in bending the Pretoria series and dolomite down to the south through an angle of some 40°." **

Naturally the different elements in the ranges would react differently to these stresses: Thus the great thickness of the massive hard rocks in the Magaliesberg range and the Dolomite, and to some extent in the Daspoort range, would offer considerable mechanical resistance to disturbance, whilst on the other hand the thinly bedded, well jointed, soft shales together with the structurally weak sandwich arrangement in the Klapperkop range would yield easily to earth movements.

The field evidence fully bears this out. The Magaliesberg quartzites maintain practically a continuous course; the Daspoort quartzite forms at least four separate ranges and has a maximum lateral displacement of about eight miles. The Time Ball Hill series shows, in addition to three ranges with a maximum lateral shift of about seven miles, an extraordinary amount of folding, minor faulting, and general buckling, especially in the southeastern portions. In fact "no locality within the limit of the Pretoria map shows more clearly the powerful earth movements to which the neighbour-

*Loco cit. p. 23.

**HALL, loco cit. P. 39.

hood of Pretoria has been subjected than the quartzite and shales of the Time Ball Hill Series in the southeastern area, on Groenkloof, Waterkloof, Garsfontein and Erasmusdam. The disturbances in this area have repeatedly brought the softer shales against the harder quartzite, and this fact has resulted in a somewhat complex structure, which is well displayed by the highly eroded surface."*

The considerable geological disturbance referred to, together with the weathering effect upon the sandwich like alternation of the hard and soft rocks in the Time Ball Hill series, has caused the appearance of flushes, gullys, ravines and valleys, in almost every conceivable direction, leaving sharply defined ridges and screes of the harder rocks exposed or outcropping.

The presence of two anticlinal domes of dolomite on Garsfontein shows that the movements have to some extent affected the lower series.

Some twenty-five faults are mentioned by Hall. Brief mention must be made of one or two. The "Meintjes Kop fault" at one point cut into the Daspoort range and displaced it 2½ miles west in Meintjes Kop. The "Struben Kop fault" further displaced the range, along a fault plane of seven miles, into the position now occupied by Struben's Kop. The next marked effect of the latter fault was to cut off the Time Ball Hill range with the result that the whole series of quartzites marked by Schanskop and Klapper Kop have been pushed south half a mile and west eight miles to Quagga Poort along the plane of the Struben Kop fault i.e. the Klapper Kop range which in fact was an easterly portion of the Time Ball Hill range has now come to lie parallel with it half a mile to the south.

The "Lynnwood fault," a branch of the "Strubens Kop fault" cuts through the Strubens Kop range near Fairy Glen whence it turns south and most probably has helped to form the deep gorge through which the Hartebeest Spruit now flows.

A few of the other faults found in the southeastern area certainly have contributed to the formation of the Waterkloof north slopes deep gully, and the Waterkloof, Wolvekloof and Garsfontein ravines.

The purpose of this paper is to show that the distribution of the vegetation remarkably follows or coincides with the irregularities described, especially that of the exposed geological strata.

But it must be emphasised, however, that ONLY THE PURELY EXPOSED OR OUTCROPPING FORMATIONS of the Pretoria Series is being dealt with. In fact, attention was almost entirely confined to the summits of the hills.

Areas, such as the pene plain in the southwestern portion of our area, where the irregular surfaces of the dolomites still contain considerable remnant soils of the Karroo rocks which once overlaid them, have been

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*HALL, loco cit., p. 36.

reserved for future study.* Similarly the valleys as well as the scree-covered portions of hill slopes, which are particularly prevalent on the south or strike aspects, will now be dealt with.

It should also be stressed that in the Magaliesberg and Daspoort ranges, the whole northern aspects, which consist of the dip slopes of *white quartzite* strata, are *exposed from summit to base*. Similarly the strike exposures of the strata involve the entire summits and upper third of the southern aspect slopes.

In the Pyramid Hills the *norites* (a hard, coarse-grained variety of basic rocks), are exposed equally on every aspect.

These conditions of the habitat have a very considerable bearing on the flora colonising them, and consequently attention must also be drawn to some important modifiers of this description.

The dip slopes on the white quartzites in their erosion break off slabs and screes, thus forming a series of ledges all the way down the sunny northern aspects of the several ranges. This means that (1) soil, humus, and rain water can be caught and thus provide firm foothold for plants including even large arboreal forms whose roots may find place between the slabs, cracks and fissures of the upper strata of this somewhat lamellated rock. (See Plate IV). (2) In the Klapperkop range erosion may have proceeded as far as the magnetite band so that almost the whole north slopes may be of this dark rock, carrying its characteristic flora. (3) The strike slopes afford some marked contrasts in the various ranges. They are steep and precipitous in the upper two ranges where the quartzites are thick and hard and impenetrable. Here they afford little foothold to any plant life, except to the hardiest, most shallow-rooted and often succulent species, the resulting vegetation being sparse and stunted. (See Plate V.)

In the Klapper Kop range however, the transverse bands of harder rock serve chiefly as retaining walls, mechanically checking the too rapid erosion of the sandwiched softer rocks. A more gently rounded contour results, which, with its more easily penetrable soil and rock, can support a fairly dense vegetable covering, usually of grass.

Ecology.

The Flora of the Pyramid Hills.

Conspicuous and exclusive on this hard variety of diabase is the tree *Kirkia wilmsii*. It occurs plentifully here, but nowhere else in the district.

*Experience in the work for my former paper "The Flora of Vryburg District in relation to the Geology" read before the fifteenth International Geological Congress, Pretoria, 1929, proved that where the formation was covered to a depth of over 4 ft. with blown sand, limestone tuffs, etc. the geology was completely masked and bore no necessary relation to the vegetable covering.

The writer knows of a similar aggregation on a softer diabase in the neighbourhood of Chunies Poort over 100 miles to the north-east. Being bird-distributed, this may account for its arrival on the norites. But its absence from the higher Magaliesberg at present seems accountable only on edaphic considerations. *Urera tenax* likewise is almost exclusive.

Another lowveld-bushveld bird-distributed tree found only on the norites in Pretoria district, is the succulent *Euphorbia ingens*.

But the chief trees colonising the outcrop on every aspect, and quite characteristic in the sense that although not *exclusive* to these hills their *frequency* proclaims this type of rock as their eu-habitat, are the following: *Vitex zeyheri and Vitex rehmanni* (only one or two casuals are to be found on the Magaliesberg); *Clerodendron glabrum* (casual on quartzites); *Pouzolzia hypoleuca* (occasionally found on the *Magaliesberg* hard quartzites); *Ximenia caffra* (sporadically but not extensively on the quartzites); *Mimusops zeyheri* (only one or two in the deep sand at the foot of the Magaliesberg).

The most prevalent tree undoubtedly is *Acacia caffra* and this so extensively covers the rugged surface as to give the green, bushed character to the outcrops (Pyramid Hills). Undoubtedly this rock in this district is the euhabitat for this species. Yet as an "indicator" of rock it is unreliable. That is, rock of this or that nature does not appear to operate as a master-factor; some other influences are equally importantly at work to determine the habitat of this plant, and it is a species well worthy of special aut-ecological study. Certain it is that it has a preference for diabase (norite, syenite, andersite and the weathered varieties); but from its almost invariable occurrence wherever screes are to be found over the diabase and shale, whether on hill or in drained valley, indicate that the physical properties of the soil (depth, aeration, ease of root penetration, etc.) play just an important a part in the case of this species as the kind of rock on which it is growing.

The norites weather into a deep, dark clay known locally as "Black Turf." Hence on every side of these hills for often as much as half a mile distant, the surface soil is of this nature. This carries what appears to be a typical flora. It is densely bushed with the ubiquitous *Acacia karroo* (ruthlessly cut down for fuel, but regenerating prolifically from self-sown seeds), and carries a grass covering dominated by *Ischaemum glaucostachyum* (found nowhere else in the district in these high proportions).

The Magaliesberg Flora.

Before the Flora colonising the rocky surface can be discussed, attention must be directed to other important ecological factors. The range is the highest feature in the district, its average height being 600 ft. above the plain from which it slopes sharply at an angle of about 35°, the whole northern faces consisting of the exposed upper bedding planes of the hard white

quartzite. Consequently (1) the summit would be the driest, most wind-exposed, elevated, coldest portions; (2) these considerations alone would lead to its carrying a different flora from the base which is wind protected, much warmer (the diurnal range 20°F. at the base whilst the extremes at the summit may be 60°F. in the winter), has a deep well-aerated, scree-admixed sandy soil, which is relatively full of humus and apart from being thus more water-retaining, it is more water-receiving from the drainage waters of the entire slopes. (See Plate IV).

Hence the flora at the base is alien to the present discussion, and it is hardly surprising to find such lowveld types as *Sclerocarya caffra;* the sand-loving *Terminalia sericea;* and *Ficus pretoriae,* the Wonderboom (almost equally large individuals are to be found in the eastern Transvaal); and large forms of the Bushveld species *Combretum zeyheri.*

Therefore it is proposed to deal with only the inhabitors of the mid- and summit slopes. (See Plate IV).

Mid-Slopes: The dominant tree from base to north summit is *Burkea africana* (broad-leaved, deciduous, wind-distributed). Owing to the modifying influences mentioned above, there is a progressive dwarfing of the habit as the exposure to the dryness, coldness, wind-exposure etc., becomes severer upwards.

Sub-dominant is *Croton gratissimum,* also deciduous. One of the most conspicuous north aspect plants is the evergreen *Chrysophyllum magaliesmontanum,* a broad-leaved sclerophyll, animal distributed. This occupies the middle to upper third of the quartzites of the three ranges, dwarfing towards the summits. It is rare to absent on the norites, rare on the dolomites, and never on southern slopes. Several other species call for special mention: *Ochna pulchra* and *Elephantorrhiza burkei,* both of which however are only subshrubs at the base of the Magaliesberg, whilst they are abundant to sub-dominant on the mid- and summit-slopes. A fairly prevalent form on the mid-slopes which becomes conspicuous and important at the summit, is *Vangueria parvifolia.* It never, however, approaches the prevalence which it attains on the Haematite of the Time Ball Hill series. A precisely similar statement must be made in regard to *Strychnos pungens* and *Landolphia capensis.* Special mention must be made of the Gifblaar, *Dichapetalum cymosum, Engl* an exceedingly poisonous plant, especially to cattle. It is a subteranean shrub which occurs from base to summit. A curious succulent, the only one of importance which occurs on the north midslopes and is, so far as is known, confined to the Magaliesberg, is *Adenia glauca,* a Passifloraceous semi-scandent herb. The stem arises from a semi-terestrial tuberous rootstock which may be very large. Apart from its colouration resembling the rocks amongst which it is growing, it is often contorted and infolded like them and frequently may bear some plant such as the fern *Pellaea hastata* growing in some convolutions of its surface.

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PLATE I

THE SUMMIT: The most notable feature, apart from the dwarfing of the few bush-like trees, that can exist there, i.e. (*Burkea africana, Ochna pulchra, Chrysophyllum, Vangueria parvifolia*) is the number of succulents. Most important among these, as being confined to the quartzites and chiefly on this range, is *Aloe peglerae*. Similarly also *Huernia loeseneriana, Cotyledon trigyna* and *Anacampseros filementosa* are almost exclusive, being relatively rare elsewhere on the quartzites in the district. *Euphorbia schinzii* is also one of the most prevalent forms confined to the quartzites; the ubiquitous *Cotyledon orbiculata* occurs here, as also *Kalenchoe thyrsiflora*; the latter being far more prevalent on the Haematite quartzites. Towards the southern aspect the low suffructicose bushy form *Rhus exisa* Thunb var. *thunbergiana* is very typical.

THE STRIKE-FACE (SOUTHERN) FLORA: (See Plate V.) On the summit edges and down the face of the steep escarpments on the strike cliffs, the only form of any size able to subsist is *Lachnopylis montana* (= *Nuxia pubescens*), an evergreen with comparatively broad leaves. The roots, in order to obtain a foothold on this impenetrable substratum, traverse great distances (20-60 ft. is common) along ledges, taking advantage of any crack or irregularity, so that by expanding to its shape, it may secure the maximum hold and casual water-supply. *Myrsine africana*, that pioneer of denser bush, is frequently to be found in the deeper shade. *Helichrysum setosum* also is constant and abundant.

Species of *Aristida* form the dominant grass types (especially *A. junciformis*) and the sedge *Scirpus Burkei, Thunb.* together with some succulents not found on the northern aspects, a yellow-flowered species of *Mesembrianthemum, Kalenchoe rotundifolia; Iboza riparia* and the poisonous climber *Bowiea volubilis*. The most notable feature, however, is the paucity of vegetation. (See Plate V).

Immediately below the precipitous cliffs, the scree-covered slopes can bear a dense vegetation (dominated by *Acacia caffra* and *Euclea lanceolata* which are most frequently covered with *Clematis brachiata*); but the underlying formations are too deeply covered to be certain, at this stage, as to their influence on the surface vegetation. But I have flown for 200 miles along the range far beyond Rustenburg, and the covering up of the *diabase and shales* below the quartzite on the south slopes of this range is general. The curious thing is that although these scree-covered, wind-sheltered slopes are deep soiled, there is little vegetation, except in the proximity of water. Even the grass covering is poor. (See Plate V).

But (1) where the rain-drainage from vertical cliffs has worn a channel deep enough to expose the diabase, there profuse vegetation occurs, and apart from *Acacia caffra* the typical arborescent forms found are *Cussonia spicata, Protea caffra* and where the water-table is comparatively near to the surface, *Celtis rhamnifolia* and *Trema bracteolata*.

(2) Where a narrow intrusive sheet of diabase has managed to penetrate through the quartzite in the middle of the range (well seen at Wonderboom Poort and slightly visible in Plate V, but chiefly along the range far out of the district to the west) there one at once finds a line of *Acacia caffra* picking this out, even over the summit and without much dwarfling of habit. The most striking evidences are the occurrence of dense clumps of *Protea caffra* even on the summit centre of the range, where small intrusions of diabase have penetrated and are exposed. The nearest such patch to the Pretoria area is to be found just east of Horns Nek.

However, the most characteristic feature of this range is the conspicuous absence of *Protea caffra* on the southern aspect summit slopes (in which position it is so abundantly and dominantly found on the Time Ball Hill range and to some extent on the Daspoort range). It is suggested that this absence is explainable largely, if not chiefly, by the absence of exposure of the underlying scree-masked soft-weathered diabase and pink shale.

The Daspoort Range Flora.

This in its main essentials repeats the flora of the Magaliesberg. It differs chiefly, apparently, on account of the differences brought about by certain physiographic structural features.

Thus the range is much lower, varying from 100 ft. to 400 ft. and the dip slopes are not so steeply inclined. Also the thickness of the hard white quartzites being only a third of the Magaliesberg it frequently happens that in the more elevated portions of the range (Meintjes Kop, Strubens Kop, Fairy Glen, West Fort) that the underlying pink shale is not entirely scree covered, and may carry its special flora on the exposures.

Suffice it to say, then, that (1) there is rarely a special basal flora containing alien forms; (2) that the north slopes are conspicuously the most colonised by the larger forms. The chief forms are *Burkea africana* (dominant) and *Ochna pulchra* (co-dominant), with *Chrysophyllum magaliesmontanum; Vangueria parvifolia, Vangueria infausta,* and *Strychnos pungens.* Occasionally *Mundulea suberosa* (a bushveld leguminous small tree) is found in this range in patches but is rare on the other ranges. One difference, however, is the number and prevalence of bushy herbs and subshrubs. Special mention must be made of the succulent-leaved *Lopholaena* (*Hertia*) *cornifolia* and *Helichrysum krausii,* both composites. The latter forms dense local communities covering the rocks. This is particularly the case in the eastern portion where the range is faulted and the strata dip at a very low angle, perhaps 15°.

Not much dwarfing of habit is seen in this range at the summits, except in the unusually high portions. Also only a few succulents occur, *Euphorbia Schinzii* being the chief. Notably, however, *Aloe pretoriensis* is frequent and locally may be abundant. But, here again, never so abundant as on the

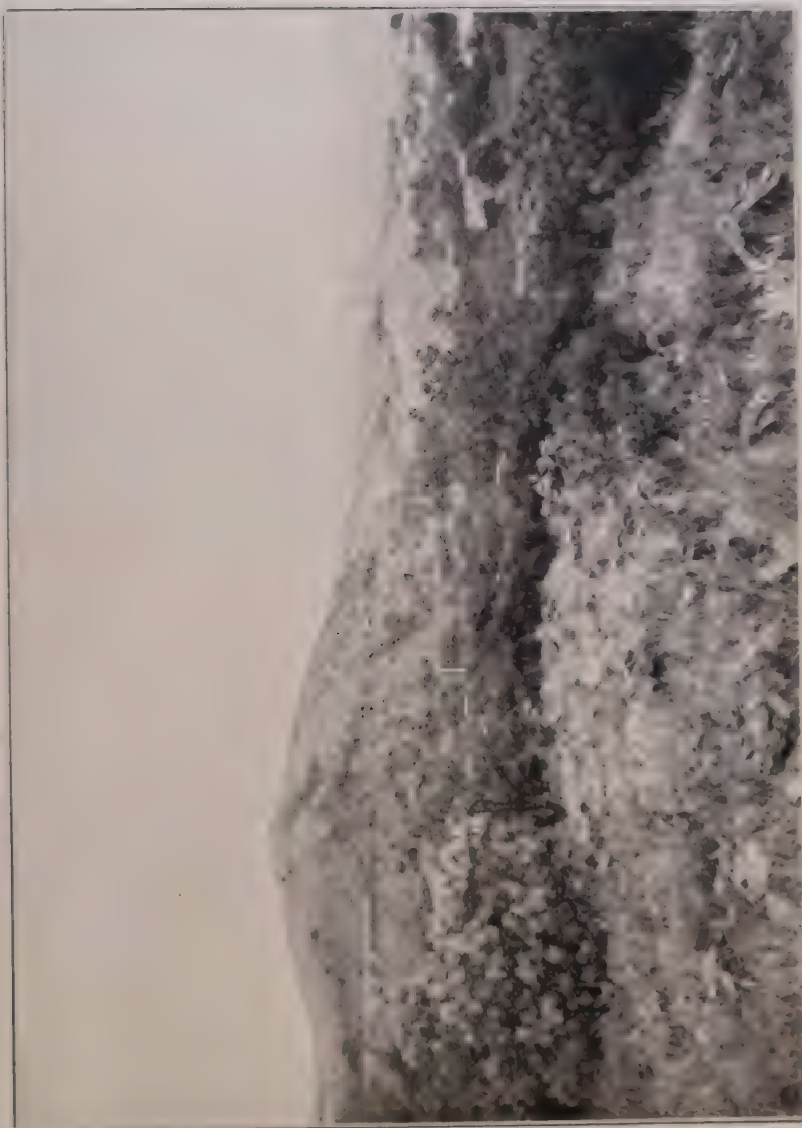

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Plate II

Haematite quartzite. *Lachnopylis montana* is far more prevalent, and is frequently accompanied by *Pittosporum viridiflorum*, a handsome broad-leafed evergreen.

The south slopes differ in being generally more bushy, particularly near the summits. This unquestionably is related to the exposures of the diabase or pink shales and possibly to its weathered derivatives contributing to the "richness" (or some such value) of the screes nearest the outcrop.

Certainly the bare diabase consistently carries *Protea caffra* (wind distributed) with *Acacia caffra* and now very frequently *Cussonia spicata*, and occasionally *Crihanthus arboreus*. The flora on each contour of exposed rock remains essentially the same where the whole range to the east of Pretoria has been bent by earth movements to lie in an almost north and south direction, instead of east and west. It seems to be the *nature of the rock* rather than aspect that counts.

The Time-Ball Hill Range Flora.

Where in this group of hills, the white quartzite or the dark magnetite quartzite bands are eroded back until the whole dip slopes are exposed, then the flora on these north slopes is almost identical with that on the white quartzites of the two northern ranges. Typically here, however, on the Haemantite (a very hard black rock) the following large forms are confined to the outcrops: *Brachylaena discolor* (almost exclusive); *Pavetta Zeyheri* (almost exclusive, rarely found on white quartzite). Next, the most prevalent forms are: *Gardenia rothmannia*, *Vangueria parvifolia*, *Strychnos pungens*, *Landolphia capensis*, *Plectronia gilfillani*, *Ochna pretoriae*, *Acokanthera venenata*. With this should be included the grasses *Tricopterix simplex*, *Cymbopogon marginatus*, *Tricholaena setifolia* and *Sporobolus pectinatus*.

The trees *Burkea africana*, *Ochna pulchra Combretum holosericeum*, *Lannaea discolor* and *Pavetta assimilis* still continue to play an important part on these rocks and the white quartzite, being confined to the outcrops.

But the important thing is that (1) the southern region of the district where these Haematite and white quartzite outcrops occur, whether irregularly in small or large patches, or whether in narrow ridges, or broad hill-sides, on any aspect, or altitude within the limits, *there* will this typical flora be found and *only there*. If the intermediate surface is scree-covered or deep-soiled, (as usually in this area) these trees disappear—except occasionally, perhaps, *Burkea africana*—and grassland is the covering, and somewhat densely also (perhaps 80% of that area). (2) that where the diabase and soft pink shale alternate with the harder rocks, and all the strata outcrop (the exposures may be seen to be almost vertical in the Muckleneuk hill (Plate I)) *there* the flora on each type of rock alternates with dramatic suddenness, so conspicuously "picking out" the underlying formation that it can be visible for miles (see Plate II). Thus from the air at 1000-2000 feet the nature

of the geology can be traced by the vegetation upon it, and conversely the composition of the communities, within limits, can be known from the nature of the rocks on the diabase and shales. Besides *Protea caffra* mention should be made of the principal grass. This is an interesting variety *Mollicoma* of the "rooi Gras" *Themeda triandra, Forsk.* This variety has an extremely localised distribution in southern Africa and as it is confined to the high-veld, Klapper Kop being its northern-most limit, it seems to be the only one of the seven forms of this grass in Africa which was mutated so far south. On the lower shaly outcrops on the southern slopes, dense communities of *Trachypogon plumosus* may be found; whilst at the base of the hill, (shale) *Eragrostis chalcantha* assumes the ascendent in percentage prevalence. However, the grassy covering of the greater part of the southern area is so variable, owing to the rapid changes of the soil, its variable depth, and physical texture, etc., caused by the irregular distribution of the disturbed beds, that closer study in conjunction with a well-organised soil survey must be made before the recorded data can be presented.

Referring again to the distribution of *Protea caffra* in the south-eastern region, it is interesting to note its occurrence in the Waterkloof ravine (see Plate III), which is a deep water-worn channel, 400 feet deep, containing a small stream. The sides slope evenly east and west, frequently exposing the irregularly distributed formation. Instead of the *Proteas* occupying the whole ravine sides, they pick out the diabase and pink shales in the odd patches in which the outcrops of these rocks occur with remarkable certainty.

The Flora of the Dolomites.

Only a brief account can be given because so little of the rock is exposed in the confines of the area; and further, the upper beds are the only ones exposed. These have been modified (1) by the contact with the extrusive diabase, and (2) by the progressive silicification of the dolomite known as "Chert."

On the pure dolomite the following plants, by their extraordinary prevalence there relative to what one finds elsewhere, really define the formation. *Cussonia paniculata; Heteromorpha arborescens* (dominant here, casual or sporadic elsewhere); *Rhus zeyheri, Gymnosporia buxifolia; Vellozia retinervis, Lannaea edulis, Massonia Sp., Eriosema Krausii,* and the grasses *Chrysopogon serrulatus, Eustachya petraea Andropagon amplectens, Heteropogon contortus, Digitaria eriantha, var. stolonifera* (glaucous form); and the fern *Pellaea hastata.*

On the Chert *Dombeya rotundifolia* is particularly abundant, as also the saxagophilous arborescent form *Ficus ingens.* This curious plant is a pioneer on bare rock surfaces where its roots and stems swell out to take the form of crevices and to overlap them so that the area of the rock is soon covered by a gnarled, twisted branching system, scarcely projecting more than a few

inches outwards from the surface. It is a broadleaved deciduous shrub, animal distributed.

Fagara capensis—a subshrub elsewhere—is here solitary in the open; *Rhoicissus cuneifolia*, casual on the quartzites as a scandent herb, is here not only relatively abundant, but often an erect, if weak stemmed, solitary shrub.

Protea Caffra has been singled out, in these discussions, from the diabase and pink shale plants, not only because it is the dominant arboreal form with distinctive habit easily recognisable from the air, but because, being a wind-distributed plant, its confining its occurrence so strictly and sharply to the outcrops of these rocks is difficult to explain on other than edaphic considerations. The pH. values of the soil, so far as the results have become available, seem to show that there is no appreciable difference between the acidity of the Haematite as compared with the diabase and pink shales a few feet from it.

A few typical determinations, all arrived at by the electrolytic method, are given below, for samples taken from surface to 9" depth about the roots of characteristic plants on summit outcrops of each rock in the southeastern area.

FORMATION.	SAMPLE.	ROCK.	PLANT.	pH VALUE.
Time-Ball Hill Series Klapper Kop.	1	Diabase and Pink Shale	Protea caffra	4.8
	2	Pink Shale	Protea caffra	4.8
	3	Haematite	Strychnos pungens	4.9
	4	Haematite	Gardenia rothmannia	4.8
	5	Haematite	Brachylaena discolor and Burkea africana	4.8
	6	Haematite	Chrysophyllum magaliesmontanum	5.1
Dolomites. Groenkloof Nursery.	7	Chert-Dolomite	Ficus ingens	6.9
	8	Chert	Lachnopylis montanum	4.4
	9	Chert and derived soils	Osyris abyssinica and Dombeya rotundifolia	6.8
	10	Chert and Dolomite	Cussonia spicata	7.1
	11	Dolomite (pure)	Gymnosporia buxifolia	7.3

TABLE OF pH. VALUES.

Note :—The plants collected in the course of these botanical surveys are preserved in the National Herbarium, Division of Plant Industry, Pretoria, where they may be consulted.)

Summary.

(1) The constant position of *Protea Caffra*, a distinct and very easily recognisable form, as observed during the course of an aerial survey, seen always to be in close association with ridges formed by the outcropping of hard quartzites, apparently irrespective of their physiographic relationships (found on every conceivable aspect, elevation or angle of slope—due to much faulting in the area) led to an extensive examination of the possible causes of this curious distribution.

(2) The observed distribution of this wind-distributed plant hardly being considered casual, nor readily admitting of an explanation from considerations of the topography (rather the contrary), a close study of the flora of the great majority of the outcrops (particularly the Haematite) was made—wheresoever situated in the area, and howsoever related to the physical features—and floristic lists prepared.

(3) These lists for each kind of rock shewed a striking consistency, so much so that the flora on contiguous formations was found to be very sharply defined.

(4) This led to the conception previously observed at Vryburg, that here also there might be a connection between the flora of the area and its geology.

(5) Work from this new angle of view was facilitated by the happy coincidence of a sandwich-like arrangement of the strata of the Time Ball Hill series, i.e. narrow bands of different kinds of rock outcropping or but very thinly covered with soil, and only a few feet apart.

(6) Confining ones attention exclusively to these outcrops, avoiding all situations where the strata were covered for more than 1 ft. of surface soil, and *studying only summit floras*, a remarkable consistency was found in the lists for each rock.

(7) Observations were extended with similar strict reservations, to the floras on the rocks of the other ranges (i.e. Daspoort and Magaliesberg quartzites; Pyramid Hills norites; and the Dolomites on Groenkloof).

(8) That as a result of these investigations the conclusions arrived at in regard to the former work* on the flora of Vryburg district in relation to the geology, may be restated here with equal confidence.

Conclusions.

It is postulated that:

(A) That where the geological formation outcrops over a large area in a locality, it is liable to carry a flora so peculiar and characteristic as to be

*"The Flora of Vryburg in relation to the Geology," read at the Fifteenth International Geological Congress, Pretoria, July-August, 1929.

readily recognisable in its principal constituents from the flora of an adjoining different outcrop of rock in the same climate.

This is well exemplified by the sandwich-like alternations of hard and soft rocks in the Time Ball Hill Series (e.g. Sunnyside Hill).

(B) That where the underlying formation is masked over a large area by superficial deposits (screes, alluvial soil) of at least four feet in depth, (possibly deeper in the case of a soft, easily weatherable rock in a moister climate), the nature of the geology may have *no influence* on the surface Vegetation.

This is well exemplified in the scree-covered lower southern slopes of the Daspoort and Magaliesberg ranges, as well as over very considerable portions of the Time Ball Hill ranges, particularly in the southeast of Pretoria.

(C) That geological faults, accompanied as they usually are by sharply contrasting variations of rock, soil, water accessability, etc., but where the physiography has not been sensibly altered, may be discernable by the suddenly altered character of the vegetation upon it.

This is well seen in the diabase intrusions often quite small in extent, through the Magaliesberg (e.g. Wonderboom Poort); and innumerable places in the southeastern area.

(D) That therefore ecological plant geography may be of material assistance to the geological surveyor and soil chemist; and, as far as macroscopic geological surveys may be made from the air, the vegetation properly understood may be of considerable value in charting geological formations, as also the recording of the occurrence and course of faults.

EXPLANATION OF PLATES.

PLATE I. View of a profile of the sandwich-like arrangement of the strata of the Time Ball Hill series, exposed in the western slopes of Sunnyside Hill.

Left to right: Weathered *sandy shale* (3-4 ft.) with Mr. Murray in front; Ferruginous Shales, (14 ft.), pink, contorted, covered with haematite screes at the surface; narrow (2 ft.) band of weathered pisolitic shale; 12 ft. band of hard Haematite (magnetite quartzite) outcropping into a distinct ridge; Diabase (4 ft.) scree-covered.

(Photo by A. O. D. Mogg, Feby., 1929).

PLATE II. Summit of Sunnyside Hill just above the profile shewn in Plate 1 depicting in the foreground the outcropping ridge of Haematite with its characteristic dark green flora, and the *Protea caffra* on the sandy- and pisolitic-shales on either side. The two sets of communities are very sharply defined.

Left to right: *Protea caffra* on sandy shale; *Pavetta Zeyheri, Vangueria parvifolia, Gardenia rothmannia* in middle distance of Haematite; in R. foreground *Chrysophyllum magalismontanum* and *Landolphia capensis*, behind which are *Combretum holosericeum* and *Vangueria infausta;* on extreme right *Protea caffra* on the pisolitic- and pink shales.

In background notice Time Ball Hill with the dark green vegetation picking out the two haematite bands over the crest and the quartzite face on the right (N. slopes).

(Photo by A. O. D. Mogg, Feby., 1929).

PLATE III. Aerial View of Waterkloof Ravine, looking north, Strubens Kop in middle distance beyond the Waterkloof Dam.

To show the apparently irregular distribution of *Protea Caffra*, Meisn. on the slopes on either side. Closer examination (see group on right side) shows that they are distributed strictly in accordance with the underlying geological formations, "picking out" the strata.

Notice in the area of the middle distance between the dam and the hills (Daspoort Range) the "Bush Groups" (Insular Clumping) referred to in the text.

(Photo by Union Air Force, March, 1929).

PLATE IV. Aerial view of the dense bush on the north dip (quartzite) slopes of the Magaliesberg at the east of Wonderboom Poort, the "Wonderboom" tree itself (*Ficus pretoriae*, Burtt-Davy) in the middle distance.

The base of the hill carries a special flora of undoubted Bushveld affinities.

Notice, however, in the plains beyond, the group of the typical trees of the quartzites (as seen on the mid slopes) indicating an almost hidden odd outlier of this rock north of the main range.

(Photo by Union Air Force, March, 1929).

PLATE V. Aerial View of the south-eastern aspect slopes of the Magaliesberg at Wonderboom Poort, showing (1) the precipitous, poorly colonised strike strata of the quartzites in the foreground and distance. (2) the scree-covered lower two-thirds of the slopes, effectually deeply covering the underlying diabase. and pink shales. (3) The general absence of Vegetation on these screes (see distance) excepting as in the left foreground where proximity to the Aapies River introduces a special condition. (4) The diabase dyke (right top) in the midst of the great thickness of the quartzites, densely colonised and so conspicuously indicated by *Acacia Caffra*, Willd. (5) The absence of *Protea Caffra*, Meisn.

(Photo by Union Air Force, March, 1929).

EXPLANATION OF TABLES.

Dom Dominant, or most characteristic form. It is usually in great, if not in the greatest, abundance.
A abundant=over 75%.
C Common=50—75%.
FC Fairly Common=20—50%.
L Little=10—20%.
FL Fairly Little=3—10%.
O Occasional, casual or sparse.
R Rare=under 1%.
VR Very Rare.

l locally, and is combined with any of the above to signify that the species is liable to occur in denser but strictly localised patches (e.g. on a pure outcrop of the rock, where elsewhere the plant's incidence is far sparser).

Ex. Exclusive, and signifies that the species is found only upon this type of rock within the confines of the area.

Sub.Ex.=Almost Exclusive (i.e. extremely rare or casual elsewhere).

* Absent

Char. Characteristic of the habitat even although its incidence is small.

70. DIE BISLANG ÄLTESTEN SPUREN VON ORGANISMEN IN SÜDAFRIKA.

Mit 5 Abbildungen

von

G. Gürich.
Hamburg.

Als älteste Fossilien führende Schichten in Südafrika konnten bisher die mehr oder minder mächtigen Kalke gelten, die von der Kapkolonie bis Transvaal und bis Südwest unter verschiedenen Namen verbreitet und deren Gleichaltrigkeit nicht gesichert ist; man rechnet sie im allgemeinen zum Transvaal-Nama-System. Eine einigermassen bestimmte Angabe über Fossilien finden wir in Rogers "Introduction to the Geology of Cape Colony" 2. Aufl. 1909, S. 84. Eine Schale "wahrscheinlich ein Brachiopod" wird aus dem Campbell-Rand-Kalk von Schmidts Drift angegeben. Eine neuere Untersuchung des Vorkommens ist mir nicht bekannt.

Abgesehen von einer weiteren Reihe von Angaben, die ich im 6. Hefte der Mitteilungen aus dem Mineralogisch-Geologischen Institut in Hamburg 1913 als irrtümlich nachgewiesen habe, liegen noch mehr oder minder fragliche Fossilien aus den Kalk- und Dolomitfunden des Nama-Transvaal-Systems vor. Ich habe 1903 [1] auf Strukturen des Otavi-Kalksteins von Urubob hingewiesen, die an Archaeocyathiden erinnern. 1915 erwähnt Rimann [2]) aus dem Schwarzkalk von Tsabisis südwestlich von Rehobot: Pseudo-Oolithe mit Molluskenkalkschalen; eine neuere Bestätigung dieser Angaben ist noch nicht erfolgt.

Eingehender beschreibt Schneiderhöhn [3]) die in den verschiedenen Schichten der Otavi-Formationen auftretenden Oolithe und organischen Ueberreste; die letzteren hat Axel Born mikroskopisch untersucht. Schneiderhöhn unterscheidet von oben nach unten:

> Schwarze Dolomite und Stinkkalke mit schwarzen Hornsteinbändern und Oolithbänke,

[1]) Centralblatt für Mineralogie usw. 1902, S.65.

[2]) Geologische Untersuchung des Bastardlandes. Dietrich Reimer 1915 S.32

[3]) Beiträge zur Kenntnis der Erzlagerstätten und der geologischen Verhältnisse des Otaviberglandes. Abhand. d. Senckenberg Nat. Ges. 1920, S.255.

hellgraue Dolomite mit hellen Hornsteinen und gefältelten Einlagerungen,
dünnplattige Kalke, wohl geschichtet,
hellgraue ungeschichtete Dolomiten.

In den obersten Schichten treten Kieseloolithe bankartig auf mit reichlich kohligen Beimengungen. Eine andere Bank enthält helle, stark verkieselte Dolomit-Oolithe. Born meint in einem Schliffe aus den oberen klotzigen Dolomiten an Archaeocyathiden erinnernde Körper zu sehen; die Strukturen waren wohl durch Umkristallisierung verloren gegangen. Die von mir beschriebene Struktur des Kalkes von Urubob ist ausgeprägter. Andere Schliffe aus dem Hornstein der Stinkkalke erinnern Born an Radiolarien. Dunkle Körner in den geschichteten Kalken und Dolomiten weisen auf einen Vergleich mit Globigerinen hin. Die von mir aus Transvaal als Cryptozoon Dessaueri [1]) beschriebenen "Hornsteinrosen" im Dolomit mögen wohl auch in Südwest vorkommen. Mir liegt ein zylindrischer Dolomitkörper mit konzentrischer Vertikalkonstruktur vor, den E. Kaiser auf Farm Auros im Otavibergland gesammelt hat; von Broili rührt eine genaue mikroskopische Beschreibung im Manuskript her; er vergleicht diese Bildung mit Newlandia concentrica Walcott. Die organische Struktur dieser dolomitischen Knolle ist erheblich deutlicher als in meinen Hornsteinrosen. Zur Altersbestimmung reichen sie einstweilen nicht aus, weil in Nordamerika ähnliche Bildungen in verschiedenen Funden der ältesten Formationen gefunden worden sind.

Unter der von Schneiderhöhn nicht geteilten Voraussetzung, dass der Schwarzkalk der Namaschichten im südlichen Teile von Südwest dem Otavikalk gleichzustellen ist, haben sich nun neuerdings als noch älter anzusehende unzweifelhafte Fossilien gefunden, deren Deutung allerdings Schwierigkeiten macht. Schon Schneiderhöhn erwähnt in der oben angegebenen Arbeit von 1920 auf Seite 207 in einer Anmerkung seinen Fund von Fossilien im Kuibisquarzit der dem Schwarzkalk unterlagert. Range teilt handschriftlich mit, dass er 1908 und 1914 je ein Fossil in den angewitterten Blöcken am Rande der durch das Kuibistal gebildeten Schlucht gefunden habe. Die Stücke gingen dann verloren und erst 1921 fand Range sie in einem übersehenen Teile seiner afrikanischen Sammlungen wieder auf. 1928 stellte er sie mir zur Untersuchung zur Verfügung. Nun ging ich der Frage aufs neue nach.

Im Gefangenenlager in Pietermaritzburg hatte ich von Schneiderhöhn einen Brief erhalten vom 22 VI 1915 aus Dutoitspan, wo er als Kriegsgefangener untergebracht war, mit der Nachricht, dass er als Assistent an der Bohrkolonne in Südwest bei Prof. v. Staff im Kuibisquarzit etwa 1 m über dem Basiskonglomerat einige wohlerhaltene Fossilien gefunden hatte, Pflanzenreste und ein Tier. Er fügte eine aus dem Gedächtnisse gezeichnete Skizze

[1]) Paläontolog. Zeitschrift 1922.

bei. Die Stücke waren 1914 Prof. v. STAFF übergeben worden; dieser starb 1915. Die Funde schienen verloren. Trotz aller Erkundigungen meinerseits waren sie nicht aufzufinden, bis ich Dezember 1928 Frau v. HECKER-STAFF bat, die noch übriggebliebenen Reste der Aufsammlung ihres verstorbenen Gatten, die in uneröffneten Kisten beiseit gestellt worden waren, mir zuzuschicken. In der einen Kiste fanden sich wohlverpackt die beiden von SCHNEIDERHÖHN gefundenen Quartzitstücke. Es liegen somit vor: Stück I u. 2 (Range), 3 u. 4 (Schneiderhöhn).

No. 1. Das Gestein ist ein hellgrauer Quarzit mit schwach rötlichen oder dunklen Wolken auf der frischen Bruchfläche; die Quarzkörnchen sind durchschnittlich 0,2 bis 0,3 mm. gross. Helle Glimmerblättchen, höchstens 1 mm gross, sind in angenähert paralleler Lagerung eingestreut. Die angewitterte Oberfläche auf dem Fossil ist rötlich-braun gefärbt. Das Fossil ähnelt einem einfachen Farnwedel mit breiter Achse und senkrecht dazu angeordneten Adern. Das breitere Ende der "Mittelrippe" sei unten, dann unterscheide ich von links nach rechts: 1. linke Fläche, 2. Mittelfeld, 3. rechte Fläche, 4. glattes Feld. Nur linke und rechte Fläche sind durch Querrippen fiederartig quergestreift. Bei 6 cm Gesamtlänge zähle ich auf jeder Seite etwa 20 Querrippen, deren Breite etwas schwankt. Die Querrippen sind voneinander durch je eine linienartige flache Rinne, die oben so bezeichneten "Adern," getrennt. Diese Rinnen und das Mittelfeld liegen vertieft und sind stärker rotbraun gefärbt, während die Querrippen mehr die graue Farbe des Gesteins erkennen lassen. Alle Reliefverhältnisse sind äusserst flach und lassen sich nur durch wechselnde flach einfallende Beleuchtung feststellen. Die linke Flääche ist gegen das Mittelfeld durch eine scharf einschneidende linienartig schmale Rinne abgegrenzt, die im unteren Drittel eine schwache Krümmung erkennen lässt. Die rechte Seite des Mittelfeldes ist nicht durch eine derartige Linie gegen die rechte Fläche abgegrenzt; hier bildet eine flach gerundete Aufbiegung die Grenze. Das Mittelfeld ist also nicht symmetrisch begrenzt. Beide Seitenflächen sind nicht einfach eben, sondern einmal fallen sie ungefähr von einer längsgerichteten Mittellinie flach nach aussen und etwas stärker nach innen ab, dann zeigen sie eine Krümmung in der Längsrichtung, indem sie beide ungefähr in gleicher Weise, im unteren Drittel etwas angeschwollen, im oberen Drittel etwas eingesenkt erscheinen. Die Querrippen der rechten Fläche stossen anscheinend senkrecht an die Abbiegung zum Mittelfelde. Die Querrippen der linken Fläche verlaufen nur in der äusseren Hälfte rein quer, d.h. senkrecht zum Mittelfelde, gegen innen, d.h. gegen den oben gekennzeichneten Grenzknick des Mittelfeldes zu biegen sie in sanfter Krümmung rückwärts, indem hier die sie begrenzenden Querfurchen besonders scharf eingesenkt sind und sich mit dem Grenzknick vereinigen. Zunächst fällt es auf, dass die Querrippen der linken Fläche etwas länger sind als die der rechten Fläche. Bei genauer Betrachtung zeigt es sich, dass die Querfurchen der

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Fig. 1

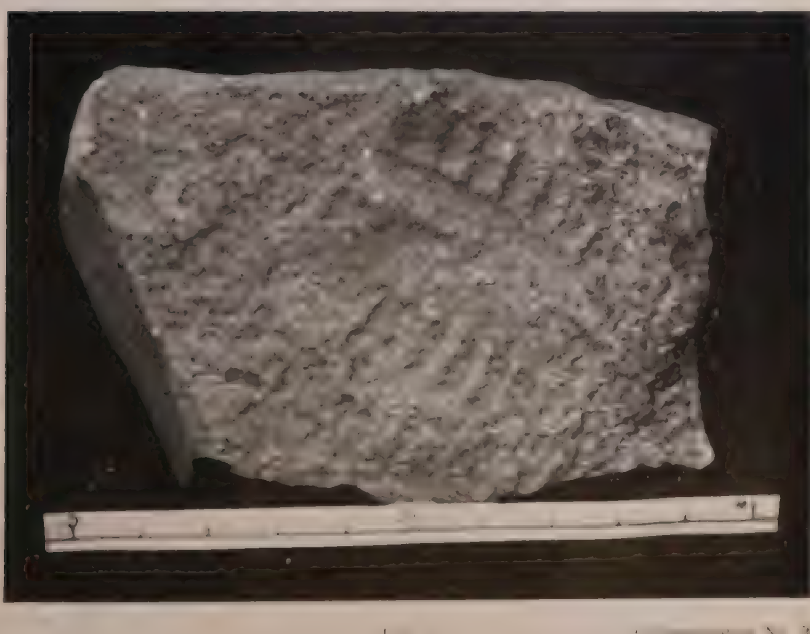

Fig. 2

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rechten Fläche gegen innen nicht so scharf einsinken wie der linken Fläche, dass sie aber in ähnlicher Weise wie diese sich rückwärts krümmen und bis an den Grenzknick reichen. Dis Symmetrielinie der Seitenflächen liegt also etwa im Grenzknick; von diesem aus sind die Querrippen recht und links einander angenähert gleich lang. Das Mittelfeld ist also nicht symmetrisch eingesenkt, sondern bedeckt noch einen schmalen Streifen de rechten Fläche. Im Bilde sind übrigens diese Umbiegungen der rechten Querfurchen, die in die Einsenkung des Mittelfeldes fallen, nicht zu erkennen. Aus diesem Verhalten geht hervor, dass Mittelfeld und Seitenflächen nicht in gleicher Weise aufeinander bezogen werden können, wie etwa die Mittelrippe und die Spreitenfieder eines Farn- oder Zykadenwedels. Es muss ein anderer Zusammenhang der Dinge angenommen werden. Bei der Grobkörnigkeit des Sandsteins sind feinere Einzelheiten der Oberfläche schwer zu sehen. Bei Vergrösserung verfliessen sie, und doch bin ich erstaunt, auch in der Photographie, z.B. in der 10. and 11. Querrippe der rechten Fläche, 5 oder 6 schräge Linien wiederzufinden, die die Qaerrippen unter einem Winkel von etwa 50° kreuzen. Auch im unteren Teile des Mittelfeldes sehe ich ähnliche feine Linien. Obwohl die seitliche Erhaltung der "Spreite" nicht einwandfrei ist, scheint mir der Umriss nicht parallelrandig zu sein, sondern im oberen Drittel ist eine grössere Breite erkennbar. Im linken Felde, in der 3. bis 8. Querrippe, von oben gezählt, fällt im umgebogenen, dem Grenzknick genäherten Ende je eine unregelmässige Vertiefung auf; es ist nicht zu entscheiden, ob diese Grübchen mit dem Fossil in Beziehung stehen, da in einem Falle die spiegelnde Quarzoberfläche in der Mitte des Grübchens erkennen lässt, dass hier ein Glimmerblättchen gesessen hat.

Das "glatte Feld" schliesst sich rechts an die rechte Fläche an, aber so, dass die Grenze zwischen beiden von unregelmässigem Gestein gebildet wird. Die Oberfläche dieses Feldes fällt durch die dicht geschlossene Oberfläche sofort in die Augen. Am oberen wie am unteren Ende scheinen lappig begrenzte Ränder nach unten umzubiegen; eine flache Längsrippe in der Mitte wird weiter unten von einer noch flacheren Längsrippe weiter rechts abgelöst. Zwischen dieser zweiten Rippe und dem umgebogenen Rande ist eine sehr flache Vertiefung erkennbar. Der Verlauf der Rippen und des Randes deutet gegen oben eine sehr schwache, nach unten eine etwas ausgesprochene Krümmung nach der Längsachse des ganzen Gebildes an. Auf dem etwas nach innen gekehrten Teile des unteren Endes ist eine feine Streifung, von der Grössenordnung der Querstreifung der einzelnen "Fiederblätter" nur eben wahrnehmbar.

No. 2. Das Gestein ist gröberkörnig als No. 1, die Quarzkörnchen sind bis über ½ mm gross. Die Schichtigkeit ist deutlicher ausgeprägt, die Glimmerblättchen sind zahlreicher und mehr parallel gelagert. Das frische Gestein ist hellgrau, die Oberfläche ockerig, eine Schichtfläche von braun-

roten und schwarzen Eisenkrusten überzogen; die eine Kluftfläche hat einen dünnen kieseligen Beschlag. Braune und schwarze Körnchen sind gegen die verwitterte Aussenseite angereichert.

Die Schichtfläche mit dem Fossil ist grobkörnig; viele Quarzkörnchen sin hier 1 mm. gross. Der Glimmer ist meist verschwunden, nur die glatten Druckflächen auf den Quarzen lassen die Stellen erkennen, wo die Blättchen gesessen haben.

Auch an diesem Stück sind zwei Seitenflächen und ein Mittelfeld zu unterscheiden; ein Unterschied zwischen oben und unten ist nicht ausgeprägt. Die stärker gekrümmte Grenze des Mittelfeldes stelle ich nach links. Die rechte Begrenzung ist grösstenteils gradlinig. Dadurch wird der Umriss etwas lanzettförmig, an der breitesten Stelle 18 mm., an den Enden 15 mm. breit; die Länge beträgt das Doppelte der grössten Breite. In der Mitte ist das Feld längs emporgewölbt, oben und unten anscheinend aufgebrochen. Die Seitenflächen zeigen auch an diesem Stücke eine Quergliederung, aber ist No. 1 ein Positiv mit gewölbten Spreitenrippen und vertieften "Adern," stellt No. 2 ein Negativ dar, dessen Spreitenrippen vertieft sind, während die "Adern" erhaben hervortreten, deren Länge nicht 10 m.m. überschreitet. Die Seitenflächen sind also schmaler als das Mittelfeld, unter sich etwa gleich breit. Von Querrippen der Seitenflächen sind jederseits 6 zu erkennen, es kommen also etwa 5 mm. Breite auf jede; sie sind demnach fast doppelt so breit und dabei kürzer als bei No. 1.

Der Umriss der ganzen Figur verschmälert sich nach unten wie nach oben. Nur rechts ist stellenweise ausserhalb der Enden der "Spreitenrippen" ein schmaler Randsaum erkennbar. Der Saum des Mittelfeldes ist sehr stark ausgeprägt, weil hier—also im Negativ—die inneren Enden der "Adern" zwischen den einzelnen Fiedern als Knötchen hervortreten.

Auch bei No. 2 ist eine Querskulptur der einzelnen Spreitenrippen angedeutet.

No. 1 und 2 stimmen also überein in einem ausgeprägten Gegensatz zwischen einem glatten Mittelfeld und den quergerippten Seitenflächen; ferner in der Andeutung einer feineren Streifung der Querrippen, die etwas schräg zu den Hauptrichtungen verläuft.

Unterschiede bestehen im Umrisse; No. 1 ist mehr bandartig, No. 2 mehr nach Art eines Melonenschnittes gestaltet. No. 1 umfasst noch ein paralleles "glattes Feld," No. 2 hat einerseits einen Saum. Weitere Unterschiede liegen in den Grössenverhältnissen der Einzelbestandteile.

No. 3. Das Gestein ist grau, nicht so grobkörnig wie No. 2 und kaum geschichtet. Die Oberfläche ist stark eisenschüssig; Glimmer ist meist zersetzt.

Die Gestalt des Fossils ist auch blattartig mit einerseits (unten) breiter werdendem Mittelfeld, einer linken und einer rechten Spreitenfläche und

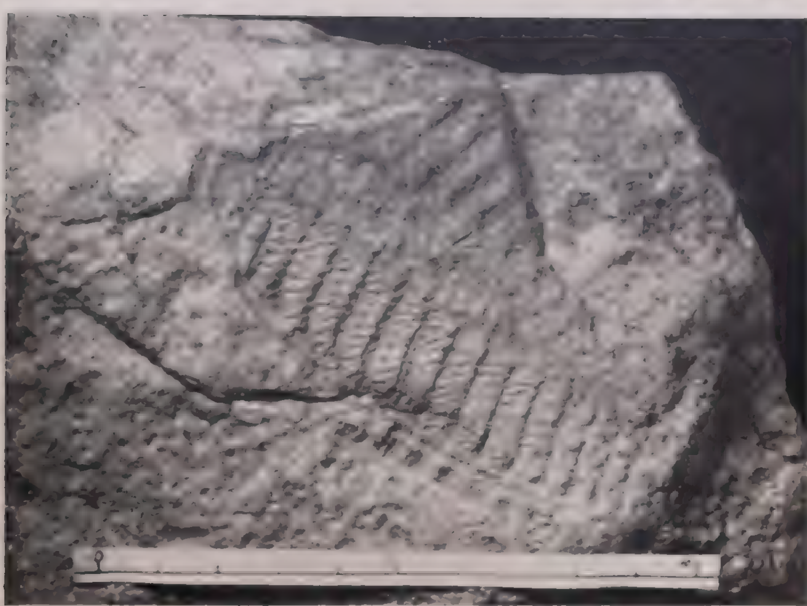

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Fig. 3

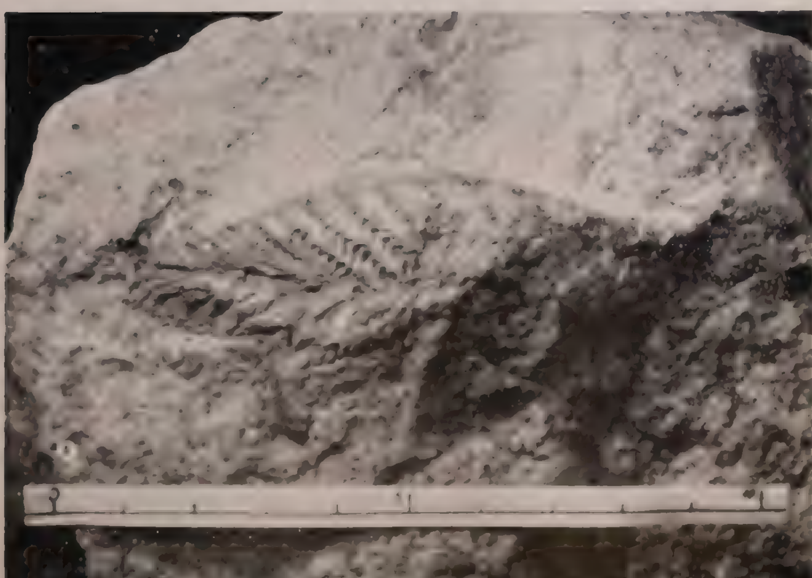

Fig. 4

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einem rechts angeschlossenen Aussenfelde. Das Mittelfeld ist gegen rechts etwas schärfer abgegrenzt als gegen links, verbreitert sich gegen unten erheblich und verliert sich im oberen Drittel in einer blossen Grenzlinie zwischen den beiden Spreitenflächen. Die Oberfläche des Mittelfeldes ist unregelmässig, es macht aber den Eindruck, als ob eine quadratische Felderung am breiten Ende durch Unregelmässigkeiten der Erhaltung gestört wäre.

Die Spreitenflächen sind flach ausgebreitet, bestehen aus ebenen Querrippen, die den Fiedern erster Ordnung eines Farnwedels entsprechen. Die Querrippen ihrerseits weisen schwach gewölbte Schrägrippen auf, von denen sie wenigstens auf der rechten Spreitenfläche unter etwa 60° geschnitten werden. Die Querrippen sind untereinander durch ausgeprägte Furchen getrennt, die ebenfalls von den Schrägrippen mehr oder minder scharf durchsetzt werden. Die Schrägrippen werden untereinander durch "Adern" 2. Ordnung getrennt. Alle diese Furchen und Schrägrippen haben aber nicht das Gradlinige, wie es etwa zwischen Echinodermen-Täfelchen erwartet werden muss, sondern sie sind unregelmässig gebogen, gewellt und sie zerfallen durch weiterhin aushaltende Vertiefungen in einen unteren und einen oberen Anteil, der sich zuweilen schwach knotig verdickt; die benachbarten Knoten in einer Reihe bilden eine wulstartige Oberkante der "Fieder"-fläche. Das rechte Spreitenfeld lässt 14 deutliche Querrippen erkennen, eine unterste und eine oberste sind aber noch angedeutet. Diese 14 Rippen kommen auf 63 mm., so dass jede 5 bis 6 mm. breit ist. Die längste Querrippe ist 15 mm. lang. Das Spreitenfeld ist im Bereiche der 3. bis 6. Querrippe gegen aussen durch einen deutlichen Saum abgeschlossen, der sich unten nach innen, also bis zum Mittelfelde fortsetzt; hier ist er mit der ersten Querrippe undeutlich verwachsen. Die untere Ecke dieser rechten Spreitenfläche wird von einem zweiten etwas breiteren Randsaume umschlossen. Die linke Spreitenfläche ist unten abgebrochen; hier mögen, wenn Symmetrie zwischen rechts und links angenommen wird, die untersten 4 Querrippen fehlen. Die nächsten 4 sind deutlich entwickelt, 5 weitere sind mit abnehmender Deutlichkeit nur eben erkennbar und überdies verkürzt, die folgenden sind nur durch schräg aufsteigende schwache kurze Wulste angedeutet. Die Schrägrippen auf der linken Seite bilden mit ihrer zugehörigen Querrippe Winkel von etwa 45°. Uebrigens ist hier an einigen weniger abgeriebenen Schrägrippchen noch eine feine Querstreifung angedeutet. Die Querrippen weichen in ihrer Stellung zum Mittelfelde wenig von 90° ab, weiter oben neigen sie sich etwas mehr der Spitze zu und auf de rlinken Seite stehen sie noch etwas steiler.

Das Aussenfeld der rechten Seite ist nur an der 7. bis 13. Querrippe angeschlossen und besteht aus einer leiterförmigen Anordnung. Die innere Seitenleiste ist die Fortsetzung des vorher angegebenen Randsaumes, verläuft parallel dem Aussensaume der Spreitenfläche und ist durch eine etwa gleich breite Furche davon getrennt. Die Sprossen sind unbedeutend

gegen die Zwischenfurchen der Querrippe verschoben und schliessen quadratische Einsenkungen ein, die auf der vierten Seite durch die Aussenleiste der Leiter abgeschlossen sind. Alle Oberflächenteile sind unregelmässig körnelig und die Aussenleiste hebt sich nur gegen innen ab, aussen geht sie in das Gestein über.

Eine Eigentümlichkeit ist noch hervorzuheben. Auf mehreren Querrippen verläuft nahe der unteren abgesetzten Grenze gegen die Nachbarrippe eine dünne rundliche, vom Gestein erfüllte unregelmässige Leiste, die aber mit dem Gestein verbunden ist; sie sieht aus, als ob sie der Steinkern eines von organischem Gewebe gebildeten Rohres wäre. Sie macht in ihrer Längsrichtung einen geschlossenen, mehr einheitlichen Eindruck, als die unmittelbar darunter folgende obere Wulstkante der nächstunteren Spreitenrippe, indem die Schrägrippchen dieser "Quer"—oder "Spreitenrippe" bis auf den Wulst hinaufziehen, der durch die Adern 2. Ordnung mehr oder minder deutlich zerteilt wird.

No. 4. Das Gestein ist hellfarbig, feinkörnig; die Körner sind 1/4 bis 1/6 mm. gross; feinschuppiger Glimmer ist reichlich eingestreut, die Schichtigkeit nicht ausgeprägt. Die Oberfläche ist etwas windgeschliffen.

Das Fossil ist blattartig und hat Aehnlichkeit mit der Spitze eines Farnwedels. Eine linke und eine rechte Spreitenfläche sind unterscheidbar, statt des Mittelfeldes ist aber nur eine Mittellinie vorhanden. Auch an diesem Stück ist ein viertes Element, ein deutlicher Randsaum rechts wohl entwickelt, der einen lanzettförmigen Umriss des ganzen Körpers annehmen lässt. Der entsprechende linke Randsaum ist aber nicht angedeutet. Von der Spreite ist nur die obere Hälfte erhalten und zwar auf der rechten Seite erheblich besser als auf der linken Seite. Drei "Fiederblätter" I. Ordnung stehen unter 25° von der Mittellinie nach vorn. Sie haben eine Sattellinie, die sich gegen aussen bis zu dem in tiefer Ebene liegenden Randsaum senkt und senden rechts und links unter spitzem Winkel "Fiedern" 2. Ordnung in Form von kurzen Wülsten zu dem die Querrippen trennenden Tale hinab, wo diese Wülste auf die entsprechenden "Fiedern" 2 Ordnung der benachbarten Querrippe stossen. Von einem sonst ähnlichen flächenhaften Farnwedel unterscheidet sich die körperliche Ausgestaltung dieser fiederähnlichen Bildungen. Weiter gegen die Spitze des Fossils hin legen sich die Sättel gewissermassen auf die Seite, so dass sie die obere Reihe der Achsen 2. Ordnung zu überdecken scheinen, während die untere Reihe dasselbe Bild gewährt wie die Schrägrippchen von No. 3.

Die obersten 4 bis 5 Querrippen stellen sich steiler, lassen kaum noch etwas von der Schrägrippelung erkennen und das Bild sieht aus, als ob sich von der Mittelrippe aus ein dünner brauneisenreicher Ueberzug über die Querrippen schöbe, der die Berippung schleierartig überdeckt, die Hauptzüge des Bildes darunter erkennen lässt, aber doch auch eigene Züge aufweist.

Es schiebt sich nämlich von der Mittelrippe aus am Grunde zwischen zwei Querrippen oder "Fiedern" 1. Ordnung ein kurzer, schmaler Ast ein, wie eine Adventiv-Fieder bei den Farnen. Der genannte Ueberzug stellt sich dort ein, wo der Randsaum oben endet, die obersten "Fiedern" sind über diesen Rand hinweggeschoben und erhalten dadurch etwas Unregelmässiges, Büschelförmiges im Aussehen. Die Enden der aufgeblähten Querrippen sind z.T. zweilappig dadurch, dass die Sattellinie ein Ende hat, während die beiden letzten "Fiederchen" 2. Ordnung nach dem Randsaume zu vorgreifen. Die obersten "Fiederchen" am Wedelende sind z.T. seitlich eingekrümmt, ähnlich wie bei Farnknospen.

Die linke Spreitenseite ist stärker aufgewölbt, abgerieben und undeutlich. Man sieht nur, dass das Prinzip der Formenbildung dasselbe ist wie auf der rechten Seite. Trotz der Verschiedenheiten zwischen No. 4 und No. 3 im Einzelnen ist doch ein gemeinsamer Grundplan in der Ausbildung der Bemusterung erkennbar.

Ehe an die Erörterung der Frage nach der Natur dieses Fossils gegangen wird, sollen ähnliche Bildungen aus anderen Gebieten zum Vergleiche herangezogen werden. Am meisten eignet sich dazu das von Pompeckj beschriebene und benannte Fossil Xenusion Auerswaldae, von dem mir der Autor Gipsabgüsse zur Verfügung gestellt hat. Auch hier sehen wir ein Mittelfeld und die beiden von Pompeckj so genannten Reihen von Seitenanhängen. Diese Seitenanhänge werden als untereinander nicht verbunden angesehen, während die ihnen entsprechenden Querrippen bei unseren Fossilien zu einer zusammenhängenden Seitenfläche verbunden sind. Dieser Gegensatz erscheint sehr gross, aber es ist doch möglich, dass nur der Erhaltungszustand diesen Unterschied bedingt. Werden also unsere Querrippen den Seitenanhängen verglichen, dann entsprechen unsere Schrägrippchen der "Querringelung" bei Pompeckj und sogar die "feine Längsriefung" bei diesem Autor ist bei den Stücken aus Afrika wenigstens angedeutet. Das gegen das spitzere Ende steilere Ansteigen der Querrippen tritt bei beiden Vorkommnissen auf.

Ein weiterer Unterschied scheint mir darin zu bestehen, dass bei unserer No. 4 eine einheitliche Mittelrippe in einigen "Seitenanhängen," "Fiederblättern" oder "Spreitenrippen" 1. Ordnung erkennbar ist, die weiter oben im Stück allerdings durch Umklappen der Spreitenrippe an deren oberen Rand zu liegen kommt, ebenso wie es bei No. 3 aussieht. Bei Xenusion scheint eine solche ungeteilte Längsrippe nicht vorhanden zu sein, aber auch nicht etwa durch blosses Umklappen zum Verschwinden gebracht zu sein, sondern hier scheint eine reine Querringelung vorzuliegen.

Noch auffälliger ist der Unterschied in der Ausbildung des Mittelfeldes, hier ist irgend ein Vergleichen nicht möglich. Eine überraschende, wenn auch wohl nur äusserliche Ähnlichkeit zeigen Fossilien aus dem Untersilur

von WHITEHOUSE im Girvangebiet, Schottland,[1]) für welche ETHERIDGE jun. und NICHOLSEN den Namen *Turrilepas Peachii* eingeführt haben. Die einzelnen Schilder weisen eine kräftige, scharf abgesetzte Mittelrippe auf und sind reihenförmig wie die Fiederblätter eines Farnkrauts an einer Hauptachse angeordnet; überall herrscht aber die straffe Linienführung, die kräftigeren Schalen aus kohlensaurem und phosphorsaurem Kalke eigen ist. Die einzelnen Schalen liegen so dicht, dass sie sich grösstenteils seitlich überdecken.

Mehr in der Art der Erhaltung als in der äusseren Form zeigen die von NATHORST[2]) zuerst abgebildeten "Spuren" aus dem Tessini-Sandstein, die auch von A. G. HÖGBOM[3]) und neuerdings, aus einem Geschiebe stammend, von H. ROEDEL[4]) beschrieben wurden. ROEDEL hat 1929[5]) dafür die Bezeichnung *Plagiogmus arcuatus* eingeführt. Es handelt sich hier um bandförmige Bildungen mit je einer Reihe von leitersprossenartig angeordneten Querrippen. Ebeson einreihig angeordnet sind die Eindrücke, die WIMAN[6]) aus dem bituminösen Olenellus-Sandstein und HÖGBOM a.a.O. Fig. 1 und Fig. 2 von der Kinnekulle abbilden.

Die Medusiten von LUGNAS können auch in Bezug auf die Erhaltung nicht recht mit den vorliegenden Formen verglichen werden, da die in dem Sandstein von LUGNAS eingelagerten Tonbänke andere Ablagerungsbedingungen erkennen lassen, durch die auch die Art der Erhaltung beeinflusst worden ist.

Geht man nun zu der Frage über, ob es sich bei den Kuibis-Fossilien um Kriechspuren oder um Abdrücke von körperlichen eingebetteten organischen Resten handelt, so müssen die Funde von RANGE (No. 1 u. 2) anders beurteilt werden wie die Funde von SCHNEIDERHÖHN (No. 3 u. 4). No. 1 ist bandförmig, steigt schwach wellenförmig auf und ab, wird in den aufgewölbten Gebieten schmaler. Das kann die Spur eines bald tiefer, bald weniger tief in die Unterlage eindrückenden, langgestreckten kriechenden Tieres sein, vorausgesetzt, dass unser Stück das Liegende der Schichtfläche darstellt. Auf der Unterseite des Tieres beiderseits der Mittellinie müsste man quer gestellte leistenförmige Bewegungswerkzeuge annehmen, deren Saum kammartig gezähnelt war; darauf würden die feinen Schräglinien zwischen je zwei Eindrücken der Bewegungsleisten hinweisen. Die Wahrscheinlichkeit dieser Erklärung wird aber verringert, wenn das "glatte Feld"

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[1]) Monograph of the Silur. Foss. of the Girvan Disfrict in Ayrshire. Fasc. 3 Taf. 20 Fig. 8, 9, 10.

[2]) Geol. Fören. Förhandl. No. 180. B. 19 1897, S.361, Taf. 5.

[3]) Bull. Geol. Inst. Univ. Upsala XI, 1925, S. 220, Fig. 3.

[4]) Zeitschr. f. Geschiebe-Forsch. II. 1926, S. 23.

[5]) Ebendort B.5, S.48.

[6]) Studien aus dem nordbalt. Silurgeb. Bull. Geol. Inst., Univ. Upsala, VI. 1902/3, Taf. IV, Fig. 5 u. 6.

mit in Betracht gezogen wird. Wir wissen nicht, ob dem glatten Felde rechts ein ebensolches auf der linken Seite entsprochen hat. Eine so breite, bei der Fortbewegung glat auf dem Boden aufliegende und mitgeschleifte Unterseite des Tieres würde für die wohl zarteren Bewegungswerkzeuge eine zu starke Beanspruchung bedeutet haben.

Bei No. 2 spricht der elliptische Umriss noch stärker gegen die Annahme einer Kriechspur und bei No. 3 u. 4 verliert diese Annahme jede Wahrscheinlichkeit. No. 3 u. 4 sind durch zur Ruhe gelangte eingebettete Bruchstücke von Lebewesen entstanden.

Welcher Art können die Stoffe gewesen sein, die die Abdrücke hinterlassen haben? Denkt man zunächst an kohlensauren Kalk, so würden Echinodermen-Bruchstücke mit scharfer Begrenzung der Täfelchen und der starren Regelmässigkeit der Skelettelemente nicht in Betracht kommen. Seewalzen allein würden eine besondere Beachtung erfordern. Eher würde man für die reichhaltige Bemusterung der Oberfläche von No. 3 an irgendwelche Muschel-, Schnecken-, Kopffüssler-Schalen mit feinen Anwachslinien und kreuzenden Längsstreifen denken, aber die Abgrenzung der verschiedenen Felder spricht dagegen. Eine solche Abgrenzung findet sich z.B. bei *Conularia;* hier sind aber die Felder im allgemeinen gradlinig begrenzt. Die gekrümmten Randlinien bei No. 2, 3, 4 sprechen dagegen. Wenn wirklich, wie es wahrscheinlich ist, No. 3 und 4 von derselben Art von Fossilkörpern abstammen, kann es sich nicht um starre Stoffe handeln, dann müssen leichte Verschiebungen, Umklappungen, Verdrückungen bei der Einbettung in den lockeren Sand möglich gewesen sein. Chitin, Zellulose, lederartige Oberflächen würden derartige Erhaltungszustände liefern—den höchsten Grad der Umformbarkeit zeigen die gallertartigen Massen der Quallen, in denen nur die Muskelstränge und die Wandungen der verschiedenen Formen von Gefässen Widerstand genug leisten könnten, um Abdrücke entstehen zu lassen.

Handelt es sich bei unseren Funden um Bruskstücke grösserer Körper oder stellen sie einen Gesamtkörper dar? Im letzteren Falle liesse sich etwa *Pennatula* zum Vergleiche herbeiziehen, es passt aber dann nicht der Aussensaum bei No. 3 und 4 dazu. Am wahrscheinlichsten handelt es sich demnach um melonenschnittartige meridionale Felder gerundeter Körper, bei denen man einen oberen Pol von einem andersartigen untern Pol unterscheiden könnte.

Lebewesen von derartiger Gestalt können unter Kalkalgen, Spongien, Coelenteraten oder Echinodermen erwartet werden. Bei den ersten beiden ist eine so ausgeprägte Felderung der Aussenseite nicht bekannt, wohl aber bei Echinodermen und Coelenteraten. Mir liegen Abdrucke von *Ctenocrinus* aus dem Unter-Devon von Daun vor, die eine überraschende äussere Aehnlichkeit mit unserem Stück No. 3 aufweisen—und doch ist es etwas anderes; die Täfelchenränder sind viel regelmässiger, ebener als unsere Grenzlinien irgend welcher Ordnung. Und wenn schon Arme mit Pinnulis im Gestein

vorkommen, würden sich auch vereinzelte eckige Täfelchen und Stielglieder finden—das ist bei uns nicht der Fall. Aehnlich ist das Bild, was manche Cystoidee bietet, z.B. *Proteroblastus Schmidti* Jaekel (Zittel—Broili, Fig. 340) aus dem Untersilur oder bei den Blastoideen *Nucleocrinus Verneuili* (Handwb. d. Nat. Pompeckj, Band IX, S. 471).

Es bleiben also nur Coelenterata übrig. Manche Ctenophoren—etwa Beroe—haben einen ähnlichen Bau. Man kann hier zwei senkrecht aufeinanderstehende, ungleichwertige Symmetrieebenen unterscheiden. Die vier meridionalen Rippenpaare sind so angeordnet, dass sie in der Sagitalebene durch ein vorderes und ein hinteres Meridionalfeld, in der Querebene durch ein rechtes und ein linkes Fangfadenfeld voneinander getrennt werden; ausserdem werden die beiden Rippen eines jeden Paares durch ein Zwischenfeld getrennt. Die Geschlechtsorgane sind an den Rippen entlang in Form blindsackartiger Gefässe angeordnet. Das Mittelfeld unserer Funde lässt sich mit einer "Rippe" der Ktenophoren vergleichen; die fiederartigen Felder entsprechen den Genitalorganen und die feineren Streifungen entsprechen den Muskelsträngen. Das "glatte Feld," Randsaum usw. sind den anderen meridionalen Feldern zu vergleichen. Aequatoriale Felder kommen bei Quallen auch vor—das würde bei *Xenusion* der Ebene entsprechen zwischen den den nach "vorn und den nach hinten" gekehrten Seitenanhängen! *Xenusion* könnte denn auch als ein derartiges meridionales Feld aufgefasst werden; das "vordere" Ende Pompecky entspräche dem Sinnespole und die eigenartigen "Leisten" am hinteren Ende in der Abbildung bei diesem Autor würden Falten aus der Umgebung des Mundpoles sein.

Entscheidende Gesichtspunkte für die Festlegung der systematischen Zugehörigkeit der Funde von Kuibis müssen von weiteren Funden abgewartet werden.

Es bleibt nun die Frage übrig, ob die vier vorliegenden Stücke zusammengehören. Die feinste bei allen auftretende Streifung scheint mir dafür zu sprechen, dass es sich um Organismen gleicher Beschaffenheit handelt, also wohl auch gleicher systematischer Stellung; ob es Stücke verschiedener Art, Gattung oder noch höherer Einheiten sein mögen, oder ob sie derselben Art angehören, muss offen bleiben. Einstweilen soll hier nur eine Bezeichnung:

Rangea Schneiderhöhni n.g., n. sp. aufgestellt werden; als Urform soll die von mir als No. 3 bezeichnete Form gelten.

TAFELKLÄRUNG.

Fig. 1: Fossil aus dem Kuibisquarzit, Stück Range No. 1.

Fig. 2: Fossil aus dem Kuibisquarzit, Stück Range, No: 2.

Fig. 3: *Rangea Schneiderhöhni*—Gürich. Aus dem Kuibisquarzit. No. 3. Fund Schneiderhöhn. Original im Harburger Institut.

Fig. 4: Fund Schneiderhöhn, Kuibisquarzit. No. 4.

Fig. 5: Dasselbe wie Fig. 4, nur in anderer Stellung und anderer Beleuchtung. Original in Hamburger Institut.

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Fig. 5

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77. UEBER KREIDE-INOCERAMEN DER SÜDAFRIKANISCHEN UNION.

Beiträge zur Kenntnis der oberkretazischen Inoceramen XI.[1])

von Privatdozent Dr. RUDOLF HEINZ,
Hamburg.

Während des 15. Internationalen Geologen-Kongresses in Pretoria 1929 habe ich die Kreide-Sammlungen folgender südafrikanischer Museen studiert:

1) Durban-Museum in Durban (Natal).

2) National-Museum in Bloemfontein (Oranje-Freistaat).

3) South African-Museum in Kapstadt (Kap der Guten Hoffnung).

4) Transvaal-Museum in Pretoria (Transvaal).

5) Museum in Pietermaritzburg (Natal).

Den Leitern dieser Anstalten, insbesondere den Herren E. C. CHUBB (Durban), Dr. E. C. N. VAN HOEPEN (Bloemfontein) und Dr. WARREN (Pietermaritzburg), möchte ich hiermit meinen besten Dank aussprechen.

Dann aber hatte ich auf der Exkursion ins Zululand unter der Führung des Herrn Dr. E. C. N. VAN HOEPEN Gelegenheit, das dortige grossartige Kreide-Profil kennen zu lernen, von dem VAN HOEPEN sagt: "The Cretaceous Beds of Zululand form a continuous series from the Aptian up to the Upper Senonian. This in itself is of great importance, for it is the only locality in the Southern Hemisphere where such a long, unbroken sequence is present." [2])

[2]) E. C. N. VAN HOEPEN, The Cretaceous Beds of Zululand. — Exkursionsführer Durban-Zululand 1929, p. 16.

[1]) Siehe Fussnote zu S. 682.

Mein Hauptaugenmerk richtete sich besonders auf die Inoceramen, deren Bearbeitung Herr Dr. VAN HOEPEN mir gütigst überlassen hat, wofür ich ihm meinen besten Dank aussprechen möchte. Die folgenden Ausführungen stellen nur einen vorläufigen Ueberblick dar. Es ist zu erwarten, dass die weiteren Felduntersuchungen noch ein grösseres Inoceramen-Material zu Tage fördern werden.

Die inoceramenführenden Kreide-Vorkommen sind ganz auf Natal beschränkt, und hier kommen sie sowohl im Pondoland wie im Zululand vor. Bisher waren von dort folgende Inoceramus-Arten beschrieben:

Inoceramus expansus BAILEY 1855
„ *andersoni* ETH. 1904
„ *volviumbonatus* ETH. 1907
„ *choffati* NEWT. 1909.

N.B.—Die bisherigen Veröffentlichungen des Verfassers über Kreide-Inoceramen sind folgende:

HEINZ, R.: Beitrag zur Kenntnis des Stratigraphie und Tektonik der oberen Kreide Lüneburgs. Mit einem Anhang paläontologischer Bemerkungen.—Mitt. a.d. Mineral. Geol. Staatsinst. Hamb. 10, p.3. Hamburg 1926.

— Das Inoceramen-Profil der oberen Kreide Lüneburgs. Mit Anführung der neuen Formen und deren Kennzeichnung. Beiträge zur Kenntnis der oberkretazischen Inoceramen I.—21. Jahresb. d. Nieders. Geol. Ver., p. 64. Hannover 1928.

— Ueber Cenoman und Turon bei Wunstorf westlich von Hannover. Zugleich Beiträge zur Kenntnis der oberkretazischen Inoceramen II.—Ibid., p. 18. Hannover 1928.

— Über Inoceramus (Actinoceramus) fasciatus G. Müll. Beiträge zur Kenntnis der oberkretazischen Jnoceramen III.—Ibid., p. 39. Hannover.

— Ueber die bisher wenig beachtete Skulptur der Inoceramen-Schale und ihre stratigraphische Bedeutung. Beiträge zur Kenntnis der oberkretazischen Inoceramen IV.—Mitt. a. d. Mineral. Geol. Staatsinst. Hamb., 10, p. 3. Hamburg 1928.

— Ueber die Oberkreide-Inoceramen Süd-Amerikas und ihre Beziehungen zu denen Europas und anderer Gebiete. Beiträge zur Kenntnis der oberkretazischen Inoceramen V.—Ibid., p. 41. Hamburg 1928.

— Ueber die Oberkreide-Inoceramen der Inseln Fafanlap, Jabatano und Jillu III im Misol-Archipel und ihre Beziehungen zu denen Europas und anderer Gebiete. Beiträge zur Kenntnis der oberkretazischen Inoceramen VI.—Ibid., p. 99. Hamburg 1928.

— Ueber die Oberkreide-Inoceramen Neu-Seelands und Neu-Kaledoniens und ihre Beziehungen zu denen Europas und anderer Gebiete. Beiträge zur Kenntnis der oberkretazischen Inoceramen VIII.—Ibid., p. 111. Hamburg 1928.

— Zur stratigraphischen Stellung der Sonnenbergschichten bei Waltersdorf i.Sa—(kestsüdwestlich von Zittau). Beiträge zur Kenntnis der oberkretazischen Inoceramen IX.—23. Jahresb. d. Nieders. Geol. Ver., p. 25. Hannover 1929.

Dabei handelt es sich um 4 auf südafrikanische Formen begründete Arten.

Die folgende Liste enthält den Ort der Beschreibung, den Fundort und den angegebenen Horizont:

	Beschreibung.	Fundort.	Angegebener Horizont.
I. expansus Bailey	Bailey: Quart. Journ. Geol. Soc. 11, 1855, p. p. 462, Tf. 13. Fig. 5.	Cliffs on coast of South Africa.	Greensand of Blackdown u. Craie Chloritée; Lower Chalk oder Upper Greensand.
I. andersoni Eth.	Etheridge: Sec. Rep. Geol. Surv. Natal and Zululand, 1903, p. 73. Tf. 2, Fig. 7-10.	Umkwelane Hill.	Turon u. Senon.
I. volviumbonatus Eth.	Etheridge: Third and Final Rep. Geol. Surv Natal and Zululand 1907, p. 73, Tf. 2. Fig. 1-6.	Umsinene-River.	„ „ „
I. choffati Newt.	Newton: Trans. R. Soc. S.A. 1, 1909, p. 45, Tf. 3, Fig. 11, 12.	Nebenflüsse des Manyuan Creek.	Emscher od. Unter-Senon.

Die von mir in den Museen sowie im Zululand festgestellten Arten sind folgende:

Inoceramus concentricus Park.
„ *andersoni* Eth.
„ *n.sp.* ex aff. *annulatus* Goldf.
„ *stillei* Heinz.
„ *dankeri* Heinz, var. *anderti* Heinz.
„ *undulato-plicatus* F. Roem.
„ *patootensis* Lor.
„ *regularis* d'Orb.
„ *impressus* d'Orb.

Beschreibung der Arten.

Inoceramus concentricus Park.

Fig. 1.

1810. *Inoceramus concentricus* Parkinson, Trans. Geol. Soc. Ser. 1. Bd. 5, p. 58, Tf. 1, Fig. 4.

1910, *Inoceramus concentricus,* Woods; Mon. Cret. Lamellibr. 2, p. 265, Tf. 45, Fig. 11; Tf. 46, Fig. 1-10; Tf. 47, Fig. 1-2.

Ein Exemplar dieser Art fand ich am Tage unserer Ankunft in Hluhluwe im Zululand (am 16.8.29) und zwar am Munyuana. Es handelt sich um eine Form, die mit der aus Europa bekannten völlig übereinstimmt.

Horizont: *Inoceramus concentricus* Park. ist in Europa eine Leitform des Ober-Gault. In demselben Niveau liegt sie in Süd-Afrika. Nach der Angabe des Herrn. Dr. van Hoepen gehören die Schichten, in denen ich das Exemplar fand, dem Alb. an.

Inoceramus andersoni Eth.

Fig. 2 u. 3.

1904, *Melina andersoni,* Etheridge: Cret. Foss. Natal, p. 73, Tf. 2, Fig. 7-10.

1907, *Inoceramus andersoni,* Etheridge: Ebenda, p. 74.

1928, *Inoceramus andersoni,* Heinz: Inoceramen-Profil, Tf. 3.

Im Museum in Pietermaritzburg hatte ich dank der Freundlichkeit des Direktors, Herrn. Dr. Warren, Gelegenheit, die Etheridge'schen Originale zu studieren. Als Typus wähle ich das in Fig. 8 dargestellte Exemplar.

Eine ganze Reihe hierher gehöriger Formen sammelte ich am 18.8.29 in der Nähe der Mündung des Munyuana in den Umsinene.[1])

Horizont: Die Art ist auch in Europa verbreitet und zwar in der unteren Abteilung des Ober-Turons, in den in Nord-Deutschland sog. Scaphiten-Schichten. Ein entsprechender Horizont scheint auch in Süd-Afrika vorzuliegen, zumal ich neben *Inoceramus andersoni* Eth., der dort massenhaft auftritt, auch *Inoceramus stillei* Heinz und *Inoceramus* ex aff. *annulatus* Goldf., also zwei weitere Vertreter des europäischen unteren Ober-Turons gefunden habe. Diese Auffassung stimmt auch im wesentlichen mit der van Hoepen's *überein.* Während der Exkursion bezeichnete Herr Dr. van Hoepen das Alter der in Frage stehenden Schichten mit "Turon-Senon."

Wen ich 1928[2]) von "prägnanten Turon-Vertreten in Süd-Afrika" sprach, so hatte ich *Inoceramus andersoni* Eth. vom Umkwelane Hill im Auge. In der derzeit aus rein vergleichenden paläontologischen Erwägungen heraus gezogenen Schlussfolgerung wurde ich bestärkt, als ich nunmehr die Zonenfolge der Kreide des Zululandes studieren konnte. Daher vermute ich, dass neben anderen Horizonten am Umkwelane Hill auch noch Ober-Turon vorkommt. Während des kurzen Aufenthaltes am Umkwelane Hill am

[1]) Frau van Hoepen, sowie den Herren Professoren Gürich, Hummel und Coleman bin ich zu Dank verpflichtet für die gütige Unterstützung beim Sammeln.

[2]) R. Heinz: 1928, V, p. 86, 87.

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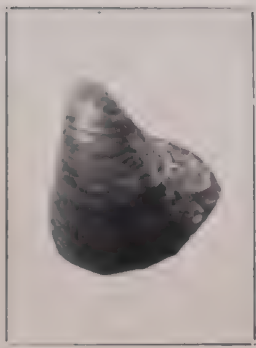

Fig. 1

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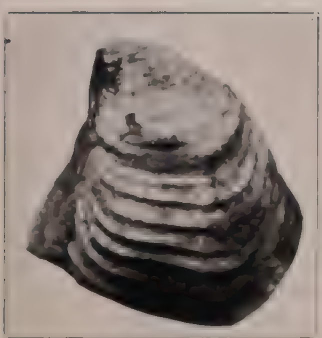

Fig. 2.

Communication No. 77.

Fig. 3

Communication No. 77

Fig. 1. *Inoceramus concentricus* Park, Umsinene Zululand. Heinz phot

Fig. 2 u. 3. *Inoceramus andersoni* Eth., Umsinene, Zululand. Heinz phot

16.8.29 ist es mir leider nicht gelungen, Inoceramen zu finden. Uebrigens soll der Original-Fundpunkt, wie mir Herr Dr. A. L. du Toit freundlichst mitteilte, auch an einer anderen Stelle des Umkwelane Hill gewesen sein. Ueberdies wurde ich in der Annahme, dass *Inoceramus andersoni* Eth. am Umsinene im Ober-Turon liegt, bestärkt durch folgende Beobachtung. Etwas höher im Profil fand ich nämlich Inoceramen des Emschers (*I. dankeri* Heinz, var. *anderti* Heinz) und darüber in einigem Abstand solche des Senons (*I. patootensis* Lor.)

Inoceramus n. sp. ex aff. *annulatus* Goldf.

In demselben Horizont, in dem Inoceramus andersoni Eth. so häufig vorkommt, fand sich auch ein Abdruck einer Form, die für das untere Ober-Turon in Lüneburg charakteristisch ist. Dabei handelt es sich um eine neue Art, deren Beschreibung noch gegeben werden soll.

Inoceramus stillei Heinz.

1928, *Inoceramus stillei*, Heinz: Inoceramen-Profil, p. 72, Tf. 2, Fig. 2.
1929, *Inoceramus stillei*, Heinz: Strat. Stellung der Sonnenbersch. p. 27.

Die hierher gehörigen Exemplare sammelte ich am 17.8.29 am Mkuzi.

Horizont: Die in Europa bisher bekannten Vorkommen habe ich bereits 1928[1]) aufgezählt. Die Art liegt im unteren Ober-Turon. Auch die Schichten am Mkuzi gehören dem Turon an, und wenn van Hoepen[2]) vermutet, dass sie einem höheren Niveau entsprechen, so stimmt das durchaus mit den europäischen Verhältnissen überein.

Inoceramus dankeri Heinz, var. *anderti* Heinz

Fig. 4 u. 5.

1928 *Inoceramus dankeri* Heinz, var. *anderti*, Heinz: Inoceramen-Profil Tf. 3.

In Schichten, die etwas jünger sind als die *Andersoni-Zone*, fand ich am 18.8.29 ein Stück Gestein, das voller z. T. hierher gehöriger Inoceramen ist. Bemerkenswert ist, dass die Exemplare ebenso dicht gedrängt liegen, wie man das gelegentlich auch in Lüneburg beobachten kann. Die Varietät *anderti* Heinz ist kleiner und flacher als der Arttypus.[3])

Horizont: In Lüneburg liegt die Art im Unter-Emscher und zwar in den mittleren *Involutus*-Schichten. Weiter kommt diese Varietät auch im Arnager-Kalk auf Bornholm[4]) vor. Auch dort handelt es sich nicht, wie bisher

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[1]) R. Heinz: 1928 I, p. 73.

[2]) E. C. N. van Hoepen: The Cretaceous Beds of Zululand. Exkursionsführer Durban-Zululand 1929, p. 15.

[3]) R. Heinz: 1928 I, p. 75.

[4]) Vergl. hierzu meine Bemerkungen in einer demnächst erscheinenden Arbeit von E. Stolley.

angenommen wurde, um Ober-Turon, sondern ebenfalls um diesen Horizont, wie auch aus dem Auftreten von *Inoceramus flaccidus* WHITE hervorgeht.

Am Umsinene liegt die Form zwischen der *Andersoni-* und *Patootensis-*Zone, was also auch auf einen entsprechenden Horizont hinweist.

Da die Stücke aus dem Zululand ungünstig erhalten sind, habe ich zwei Exemplare von Lüneburg abgebildet, darunter den Typus (Fig, 4).

Inoceramus undulato-—plicatus F. ROEM.

1849, *Inoceramus undulato-plicatus,* ROEMER: Texas, p. 402.

1852, *Inoceramus undulato-plicatus,* ROEMER: Kreidebildung. v. Texas, p. 59, Tf. 7, Fig. 1.

1928, *Inoceramus undulato-plicatus,* ROEM., var. *michaeli,* HEINZ: Inoceramen-Profil, p. 76, Tf. 3.

Diese interessante Form war bisher nur auf der Nordhalbkugel bekannt. Die Fundorte sind bereits 1928 von mir angegeben. Während meines Aufenthaltes in Süd-Afrika war mein Hauptaugenmerk mit darauf gerichtet, festzustellen, ob die Art nicht doch auch dort vorkommt. Der Zufall wollte es, dass ein vollständiges, gut erhaltenes Exemplar von *Inoceramus undulato-plicatus* F. ROEM., welches mit unseren Vorkommen vollständig übereinstimmt, unmittelbar nach unserer Ankunft an der False Bay am 19.8.29 am sandigen Ufer gefunden wurde. Diese Stelle kommt jedoch nicht als primäre Lagerstätte in Frage. Das Stück stammt wahrscheinlich aus der Umgegend und ist durch irgendeinen Umstand an diesen Ort gelangt. Auf der von uns darauf besuchten Halbinsel in der False Bay ist jedoch das Lager nicht zu suchen. Hier steht nämlich Ober-Senon an, in dem die *Regularis*-Gruppe sehr häufig vorkommt.

M.E. besteht kein Zweifel, dass das Stück aus dem Zululande stammt, zumal von hier oben bereits andere Emscher-Inoceramen (*I. dankeri* HEINZ, var. *anderti* HEINZ) angeführt wurden.

In dieser Ansicht werde ich bestärkt durch die im Durbaner Museum gemachten Feststellungen. Während einer Expedition ins Pondoland hatte Herr CHUBB u.a. zwei bisher unbestimmte Inoceramen mitgebracht, die sich als zu obiger Art gehörige Exemplare herausstellten.[1]) Auch diese stimmen vollständig mit denen der Nordhalbkugel überein.

Somit ist durch die Feststellung dieser Art, die auf der Nordhemisphäre ein Leitfossil des Emschers ist, diese Stufe auch in Süd-Afrika nachgewiesen.

Die Vorkommen auf der Nordhalbkugel sind bereits von mir angegeben.[2])

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[1]) Herrn Dr. A. L. DU TOIT, der mich auf diese bisher unbekannten im Durbaner Museum aufbewahrten Inoceramen gütigst aufmerksam machte, sei an dieser Stelle bestens gedankt.

[2]) R. HEINZ: 1928, IV, p. 10.

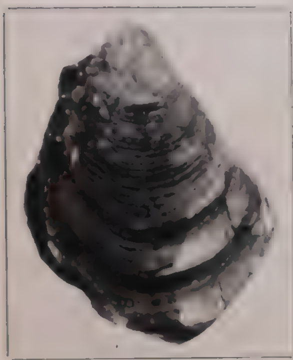

Fig. 4.

Communication No. 77

Fig. 5.

Communication No. 77

Fig. 6a

Communication No. 77.

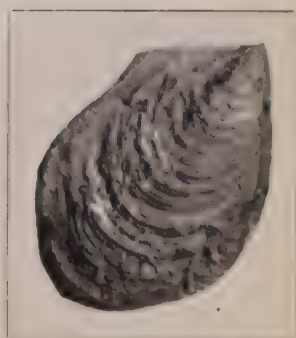

Fig. 6b.

Communication No. 77

Fig. 4. u. 5. *Inoceramus dankeri* Heinz, var. *anderti* Heinz, Luneburg, Deutschland, ob. Unter-Emscher, mittl. Involutus-Sch. Heinz. phot

Fig. 6a, 6b. *Inoceramus patootensis* Lor., Umsinene, Zululand. Heinz phot

Inoceramus patootensis LOR.

Textfig. 6a u. 6b.

Einen Vertreter diser Art fand ich am 18.8.29 am Umsinene. Es handelt sich um ein doppelklappiges Exemplar, an dem die hintere Radialfurche erkennbar ist und welches in der keilförmigen Gestalt sowie in der Skulptur mit unseren Formen übereinstimmt.

Somit ist also auch *Inoceramus patootensis* LOR. zum ersten Male in Süd-Afrika und damit gleichzeitig auf der Südhalbkugel festgestellt.

Horizont: Nach der Angabe von Dr. VAN HOEPEN gehört das dortige Lager ins mittlere Senon, was also mit den deutschen Vorkommen übereinstimmt. *Inoceramus patootensis* LOR. liegt in Deutschland im oberen Granulaten Senon, in den Marsupiten-Schichten.

Im übrigen sei auf meine früheren Ausführungen verwiesen.[1])

Inoceramus regularis D'ORB.

Die Art wurde in vielen Exemplaren auf der von uns am 19.8.29 besuchten Halbinsel in der False Bay gesammelt. Weiterhin liegt sie im Durbaner Museum aus dem Pondoland vor.

Horizont: An der False Bay liegt die Art im Ober-Senon, also im selben Niveau, in welchem sie auf der übrigen Erde auftritt.

Inoceramus impressus D'ORB.

Ein hierher gehöriges Exemplar mit der typischen Diagonalleiste wurde ebenfalls an der False Bay am eben genannten Ort gefunden. Es möge auf meine früheren Ausführungen verwiesen sein.[2])

Horizont: wie *Inoceramus regularis* D'ORB.

Inoceramus expansus BAILEY wurde nicht beobachtet. Bei dieser Art handelt es sich um einen gut ausgeprägten Senon-Typus.

Inoceramus volviumbonatus ETH., als dessen Typus ich Abb. 1 wähle, gehört in die Gruppe des *Inoceramus concentricus* PARK. und dürfte auch dem Gault zuzurechnen sein.

Inoceramus choffati NEWT. ist an Hand der Abbildung nicht sicher zu erkennen. Es dürfte sich vielleicht um eine Form aus der Gruppe des *Inoceramus virgatus* SCHLÜT. aus dem Ober-Cenoman handeln.

Die Abbildungen zeigen natürliche Grösse. Die Originale befinden sich im unten angegebenen Institut.

Hamburg, Mineralogisch-Geologisches Staatsinstitut,
Lübecker Tor. 22
im Januar 1930.

[1]) R. HEINZ: 1928 I, p. 79 u. Tf. 3.
R. HEINZ: 1928 IV, p. 10.

[2] R. HEINZ: 1928 IV, p. 22.

78. LA GÉOLOGIE GÉNÉRALE DU HAUT KATANGA.

PAR

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RESUMÉ.

Le Katanga constituait une cuvette de sédimentation creusée dans le socle continental ancien.

Des formations lacustres, et marines en partie, s'y sont accumulées.

Celles de ces formations, reconnues, jusqu'ici, dans le Haut-Katanga, appartiennent seulement à deux systèmes, que sépare une discordance.

Le système supérieur, fossilifère (rhétien), correspond au "Stormberg" del 'Afrique Australe. Grès, schistes ,charbon.

Le système inférieur est azoïque (âge indéterminé). C'est un énorme empilage de dépôts accumulés en concordance générale, dans des conditions spéciales.

A la base règne un épais complexe conglomératique renfermant une puissante intercalation schisto-dolomitique-cherteuse, qui englobe la "Série des Mines."

Le niveau supérieur du complexe est d'origine glaciaire. Correspond-il à la "Dwyka Tillite"?

Sur lui reposent de volumineuses séries schisto-calcaro-grèseuses.

Représentent-elles les couches d'Ecca et de Beaufort?

Seul, le système inférieur est plissé.

Dans le Haut-Katanga, les poussées, issues du Sud, et souvent violentes, ont engendré de grandes failles longitudinales inverses, avec, par places, charriages.

Les cas d'effondrement sont douteux; les accidents transversaux rares et sans amplitude.

La plupart des gisements minéraux jalonnent ces failles longitudinales.

Leur origine est tectonique.

Leur forme actuelle pourrait être secondaire.